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Society
FOR THE
Promotion of Engineering Education.

PROCEEDINGS
OF THE
THIRD ANNUAL MEETING,
HELD IN
Springfield, Mass., September 2, 3, 4, 1895.

Volume III.

EDITED BY
MANSFIELD MERRIMAN, HARRY W. TYLER,
JOHN B. JOHNSON, C. FRANK ALLEN,
Committee.

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1896.

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The Society for the Promotion of Engineering Education is an outgrowth of the Engineering Congress held at Chicago in 1893. The success of the section of Engineering Education was such as to suggest the value of a permanent organization, which was there effected. Meetings are held annually. In 1894 the Society met in Brooklyn, with the American Association for the Advancement of Science, and in 1895 at Springfield, Mass., with the same Association. The meetings have been well attended, the papers interesting, and the discussions animated and instructive. The opportunities for engineering educators and others having community of interests, to meet both socially and for informal comparison of views, is not the least of the benefits to be derived from the Society. The present membership of one hundred and eighty-eight includes very many of the ablest and best known of the engineering teachers of this country, as well as several eminent foreign professors of engineering. Eighty-six institutions are represented, including nearly all colleges giving instruction in engineering. Geographically, there are members from thirty-seven States, as well as Canada and five European countries. It is believed that good has already resulted, not merely to the members, but also to the institutions

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represented by them. Greater opportunity for good is possible, and would result from increased membership. Engineering is a broad profession, and this Society is intended to include representatives of all branches of the profession. Educators interested in engineering, whether mining, electrical, chemical, sanitary, mechanical or civil, or engaged in allied professions, can properly expect to receive benefit from the Society, and will be welcomed as members. Nearly, if not all of the branches mentioned are already represented in the membership. In the last quarter of a century, it is doubtful if progress in any direction has been more marked, more rapid, or more substantial, than progress in Engineering Education. If Still more perfect and substantial results are to be secured in future, there is need that attention should be given to educational methods, and to better organized and more systematic effort, and to this end the Society for the Promotion of Engineering Education is in position to perform an important function. It hopes to receive the moral support of institutions as well as of the individuals who represent them.

The Fourth Annual Meeting of the Society will be held in Buffalo, beginning on Thursday, August 20, 1896. The Annual Convention of the American Association for the Advancement of Science opens the following Monday in the same city.

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1895-'6.

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MANSFIELD MERRIMAN, HARRY W. TYLER.

On Uniformity of Symbols for Engineering Text-Books.

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Marvin, Frank O., Lawrence, Kans.	Professor of Civil Engineering, University of Kansas	1893
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RANDOLPH, LINGAN S., Blacksburg, Va.	Professor of Mechanical Engineering, Virginia Agricultural and Mechanical College	1894
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RICHTER, ARTHUR W., Madison, Wis.	Assistant Professor of Steam Engineering, University of Wisconsin	1894
RICKER, NATHAN C., Urbana, Ill.	Dean of College of Engineering, University of Illinois	1894
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VEDDER, HERMAN K., Agricultural College, Mich.	Professor of Mathematics and Civil Engineering, Michigan State Agricultural College	1894
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WADSWORTH, MARSHMAN E. Houghton, Mich.	Director, Michigan Mining School	1895
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WEIHE, FREDERICK A., Newark, Del.	Professor of Mechanical Engineering, Delaware College	1893
WHITNEY, NELSON O., Madison, Wis.	Professor of Railway Engineering, University of Wisconsin	1893
WILCOX, RALPH M., South Bethlehem, Pa.	Instructor in Civil Engineering, Lehigh University	1894
WILLIAMS, SYLVESTER N., Mt. Vernon, Iowa.	Professor of Civil Engineering, Cornell College	1893

Name and Address.	Title.	Date of Membership.
WILMORE, JOHN J., Auburn, Ala.	Professor of Mechanical Engineering, Alabama Polytechnic Institute	1894
WING, CHARLES B., Stanford University, Cal.	Professor of Structural Engineering, Leland Stanford Junior University	1895
WOOD, DE VOLSON, Hoboken, N. J.	Professor of Mechanical Engineering, Stevens Institute of Technology	1893
WOODWARD, CALVIN M., St. Louis, Mo.	Dean of Polytechnic Department, Washington University	1894
WOODWARD, ROBERT S., New York, N. Y.	Professor of Mechanics, Columbia College	1893

Total number of Members, 188.

DISTRIBUTION OF MEMBERS.

Alabama	3	Minnesota	8	Vermont	2
California	4	Mississippi	1	Virginia	2
Colorado	2	Missouri	10	West Virginia	2
Connecticut	3	Nebraska	3	Wisconsin	7
Delaware	2	New Hampshire	3	Wyoming	1
Idaho	1	New Jersey	5	District of Columbia	2
Illinois	7	New York	25	Canada	3
Indiana	13	North Carolina	1	England	4
Iowa	3	North Dakota	1	France	1
Kansas	3	Ohio	6	Switzerland	1
Kentucky	1	Pennsylvania	18	Russia	1
Louisiana	2	South Carolina	1	Germany	2
Maine	2	South Dakota	1	Total	188
Maryland	2	Tennessee	4		
Massachusetts	18	Texas	2		
Michigan	4	Utah	1		

37 States, 5 European Countries, Canada, and the District of Columbia.

CONSTITUTION

OF THE

Society for the Promotion of Engineering Education.

1. Name.—This organization shall be called the Society for the Promotion of Engineering Education.

2. Members.—Members of this Society shall be those who occupy, or have occupied, responsible positions in the work of engineering instruction, together with such other persons as may be recommended by the Council.

The name of each candidate for membership shall be proposed in writing to the Council by two members to whom he is personally known. Such names, if approved by the Council, shall be voted on by the Society at the annual meetings.

3. Council.—The Council of this Society shall consist of twenty-one members chosen from the Engineering Schools of the United States and Canada, and one-third of the Council shall retire annually.

Any member of this Society shall be eligible to election to the Council, provided that not more than one member of the Council shall be from any one school.

Members of the Council shall be elected by ballot by the Society at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

4. Officers.—There shall be a President, two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year. They shall be chosen by vote of the members at the annual meeting. Members of the Council only shall be eligible to these offices.

5. FEES AND DUES.—The admission fee shall be three dollars and the annual dues three dollars, payable at the time of the annual meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the proceedings, and such members shall be notified thereof by the Secretary one month previous to the annual meeting.

6. MEETINGS.—There shall be a regular meeting occurring at the time and place of the meetings of the American Association for the Advancement of Science, or of some one of the National Engineering Societies, or otherwise as the Council may determine.

7. PUBLICATIONS.—The proceedings of the Society, and such papers or abstracts as may be approved by the Council, shall be published as soon as possible after each annual meeting.

8. AMENDMENTS.—This Constitution may be amended by a two-thirds vote at any regular meeting, after action thereon by the Council.

RULES GOVERNING THE COUNCIL.

First. The officers of the Society shall constitute a committee to arrange the time and place of the annual meeting, and also to prepare a program for the same.

Second. The reading of papers shall be limited to fifteen minutes each, and abstracts of the same of about 300 words or less shall be printed when practicable and distributed in advance to the members.

Third. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

PROCEEDINGS.

MONDAY, SEPTEMBER 2, 1894.

MORNING SESSION, 9:30 O'CLOCK.

The third annual meeting of the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION was held in the High School Building, Springfield, Mass., in conjunction with the meetings of the American Association for the Advancement of Science. The meeting was called to order by the President, George F. Swain, who at once proceeded to read the Annual Address.

The Secretary read his report for the year, which was accepted.

The Treasurer also presented his report, properly endorsed by the Auditing Committee; this was also accepted.

It was then moved and voted that a nominating committee, to consist of five members, be appointed by the President, and instructed to report a list of candidates for the Council at the morning session on Tuesday.

The report of the Council was then read by the Secretary.

It recommended an amendment to the Constitution raising the annual dues to three dollars, to take effect at and after the next annual meeting.

Library
N. C. State College

On motion of Prof. Fava, Section 5 of the Constitution was amended in the way suggested, two-thirds having voted in the affirmative, making the reading of Section 5 "the annual dues three dollars" instead of two dollars.

It was voted that the election of members of the Council be made a part of the business for Tuesday morning.

The admission of new members was then taken up, and the following who were recommended by the Council were elected: T. Raymond Beyer, Louis G. Carpenter, Edward R. Cary, George S. Clark, Harry T. Cory, Charles R. Cross, Thomas M. Drown, George H. Hamlin, William K. Hatt, Arthur E. Haynes, Clement R. Jones, Henry A. Lardner, T. C. Mendenhall, Frank H. Neff, William D. Pence, Michael I. Pupin, Charles R. Richards, Robert H. Richards, Wallace C. Riddick, William H. Schuerman, George D. Shepardson, Charles H. Snow, William M. Towle, John L. Van Ornum, Joel E. Wadsworth, Marshman E. Wadsworth, Elton D. Walker, Charles B. Wing.

A letter of greeting and good-will from Past President DeVolson Wood was read by the Secretary, after which the reading of papers was taken up, as follows:

The first paper was the report of the Committee on "Entrance Requirements for Engineering Colleges," which was read by Prof. Frank O. Marvin, Chairman of the Committee. It received an extended discussion, in which the following professors took part, viz: Professors Merriman, Fava, Johnson, Mees, Bull, Galbraith and Raymond.

Professor William G. Raymond read a paper on

"The Scope of an Engineering College," which was followed by an animated discussion by Professors Allen, Flather, Fava, Dwight Porter, Marvin, Raymond, and Mr. Kent.

The paper by Professor Louis E. Reber on "The Present Requirements of American Engineering Colleges in Non-professional Studies," was read by Professor F. O. Marvin.

The meeting then adjourned to the afternoon session.

AFTERNOON SESSION, 2 O'CLOCK.

President Swain in the chair.

Papers were read in the following order:

A paper entitled "The Elective System as Adopted in the Michigan Mining School," by Professor Marshman E. Wadsworth, was read by Professor W. G. Raymond, and discussed by Professors Merriman, Galbraith, Ordway and Hofman.

Professor Leander M. Hoskins' paper on "Graphic Methods in Engineering Education," was read by Prof. Mansfield Merriman, and was discussed by Professors Johnson, R. S. Woodward, Merriman and Fava.

A paper by Professor Ira O. Baker, on "Specifications for Text-Books," was read by Professor J. B. Johnson. The President and Professors Marvin, Jacoby, Fava, Merriman and Allen took part in the discussion which followed.

The afternoon's program concluded with a paper by Professor Charles H. Benjamin on "The True Place of Drawing and Shopwork in Engineering Colleges," which was read by Professor Cady Staley.

Professors Spangler, Ordway and Higgins took part in the discussion.

The following were appointed by the President to constitute the Committee on Nominations: H. S. Jacoby, S. N. Williams, A. Kingsbury, H. K. Vedder, D. Porter.

A reception at the United States Armory immediately following adjournment was attended by many of the members.

TUESDAY, SEPTEMBER 3, 1895.

MORNING SESSION, 9:30 O'CLOCK.

The following recommended for membership by the Council were voted for by ballot and declared elected: William L. Ames, Charles S. Brown, Thomas Gray, Harry E. Smith.

The program for the morning was taken up. Professor Bull's paper on "Graduation, Thesis and Degrees" was read by the author, and was in some sense a continuation of the papers by Professors Ricketts, Swain and Thurston of a year previous. A very full discussion was provoked by the paper, and in the discussion Professors Johnson, Lanza, Gray, Williams, Doolittle, Marvin, Raymond, Merriman, Allen and Bull, and Mr. Kent took part.

"Modified Requirements for Graduation of Students who have taken full Literary Courses" was the title of a paper by Professor Ira N. Hollis, which was read by Professor Flather, the discussion being by Professors Bull and Kingsbury.

A paper on "The Comparative Value of Graduate Study in Engineering Courses," by Professor William H. Burr, was read by Professor Kingsbury and discussed by Mr. Kent.

Then followed the reading by Professor Allen, of Professor Lingan S. Randolph's paper on "The Economic Element in Technical Education." The discussion on this paper included remarks by Mr. Kent and Professors Flather, Galbraith and Kingsbury.

"The Unsymmetrical Development of Courses in Engineering." May an engineering college with profit allow one department to become highly developed at the expense of other departments? a paper by Professor Frederick R. Hutton, was read by Professor Johnson; after which Mr. Elmer L. Corthell presented his paper on "The Civil Engineer of the Twentieth Century." The discussion of this paper by Professors Merriman, Johnson, Lanza and Raymond and Mr. Kent closed the literary exercises of the day.

The Nominating Committee reported the following names in nomination for the Council: C. F. Allen, C. L. Mees, M. Merriman, J. M. Ordway, W. G. Raymond, C. Staley, R. S. Woodward. A ballot taken resulted in their election. The Committee was continued to report nominations for officers of the Society on Wednesday morning.

Announcement was made of the excursion to Holyoke, planned for the afternoon.

No session was held in the afternoon. Many members visited Holyoke, the special objects of interest being the dam under construction, and the testing pit in operation. Other members found points of interest to visit in the city.

WEDNESDAY, SEPTEMBER 4, 1895.

MORNING SESSION, 9:30 O'CLOCK.

Two new members recommended by the Council were balloted for and elected, Elmer L. Corthell and Elmer S. Farwell. On motion it was voted that a committee of five be appointed by the President to arrange a system of symbols for engineering textbooks, looking toward a greater uniformity in such notation.

A cordial invitation to hold the next annual meeting of the Society in Nashville, Tenn., was received from the Chamber of Commerce of that city, supported or endorsed by the Mayor, Board of Public Works, City Council and Tennessee Centennial. The Secretary was directed to reply to this invitation in a suitable manner.

The following officers of the Society were elected by ballot in accordance with the report of the Nominating Committee: *President*, MANSFIELD MERRIMAN, Lehigh University; *Vice-Presidents*, FRANK O. MARVIN, University of Kansas; CADY STALEY, Case School of Applied Science; *Treasurer*, JOHN J. FLATHER, Purdue University; *Secretary*, C. FRANK ALLEN, Massachusetts Institute of Technology.

The program arranged for was taken up and the following papers were presented:

Professor Carl L. Mees read his paper on "A Course of Study in Physics," and Professors Galbraith, Merriman, Kingsbury and Mees entered into the discussion. This was followed by Professor Charles L. Crandall's paper on "A General Course in Civil Engineering," what professional studies should be included in a four years' course in civil engineering, and how much time should be given to each, when no specialized courses in civil engineering are offered. This was briefly discussed by the President.

A paper on "Sanitary Engineering," as part of a series of discussions on "Civil Engineering in Specialized Courses," was read by the author, Professor Charles C. Brown. This was discussed by Professors Galbraith, Marvin, Dwight Porter and C. C. Brown. Then followed the reading of Professor Mansfield Merriman's paper on "A Specialized Course in Geodetic Engineering," and the paper on "A Course in Astronomy for Engineering Students," by Professor George C. Comstock, which was read by Professor Johnson. Both of these papers were included in the discussion which followed, and in which Professors Marvin and Allen took part.

The paper on "A Course of Study in Mechanics," read by the author, Professor Robert S. Woodward, provoked earnest discucsion, in which Professors Galbraith, Mendenhall, Merriman, Johnson, R. S. Woodward and Mr. Kent joined. This was followed by the last paper of the morning, "A Course in Biological Sciences for Engineering Students," by Professor Christopher W. Hall, which was read by Professor Jacoby.

AFTERNOON SESSION, 2:30 O'CLOCK.

The regular program was at once taken up.

The first paper was presented by Professor H. W. Spangler on "Mechanical Engineering," subjects to be treated and time given to each.

Professor Heinrich O. Hofman's paper on "The Equipment of Mining and Metallurgical Laboratories" was read in abstract by the author. The President at this time called the attention of the members to the desirability of securing a larger membership from among the representatives of the Mining and Electrical Engineering Courses.

Professor John B. Johnson read his paper on "A Course of Instruction in Engineering Materials," which was discussed by Mr. Kent and Professors Galbraith and Merriman. A paper entitled "Teaching Industrial Applications of Electricity," by Professor George D. Shepardson, was then presented. This was followed by the last paper of the session, "A Course in Mining Engineering," which was read and carefully discussed by Professor Hofman.

The President appointed as the Committee on Uniformity of Symbols for Engineering Text-Books, I. O. Baker, J. B. Johnson, Wm. Kent, J. Galbraith, F. R. Fava, Jr.

A vote of thanks was passed to the Citizens' Committee and to the Holyoke Water Power Company for courtesies received.

The Society also unanimously passed a vote of thanks to the retiring Secretary for his indefatigable energy and his valuable services to the Society.

A motion to adjourn, which was carried, closed the meeting.

The sessions were well attended and the papers were received with interest and discussed with vigor.

J. B. Johnson, *Secretary.*

Report of the Secretary.

Your Secretary begs leave to submit the following report for the past year:

There were, at the close of the last meeting, 156 members. There have been received during the year, 28 applications for membership, and many more will doubtless be received at this meeting. It is probable, therefore, that our numbers will thus be raised to over two hundred. Most of these are professors in our leading engineering schools, all such schools being represented, I believe, by one or more members.

The interest taken in our work is attested by the remarkably full and strong program of papers to be read at this meeting. There is no question now as to the importance of the work this Society has set itself to perform. It is nothing less than shaping the future of technical education, not only in America, but by example to all the world. The published volumes of our proceedings have a considerable sale abroad, and the engineering education therein outlined has recently been the subject of a stirring paper and an extended discussion before the leading Society of Engineers and Architects of Germany. They are finding out that they have many things to learn from us, especially in the matter of experimental and laboratory methods.

While the Society has passed another year and paid all its bills without raising the annual dues, yet the entrance fees of three dollars each have been devoted to current expenses. As these will diminish in number, while our expenses will increase with the natural increase in the size of our volumes, it is certain that the annual dues will ultimately have to be raised to three dollars. If our expenses can be limited to the necessary outlay for stationery, printing and postage, as at present, the sum of three dollars annual dues will probably suffice to give us our proceedings in cloth-bound volumes indefinitely.

There were printed and bound 500 copies of Vols. I. and II. and we still have on hand about 300 copies of Vol. I. and 280 of Vol. II.

The great amount of matter offered at this meeting has been commented on, and some may feel that it is burdensome. But since the matters discussed are now live questions in nearly all engineering schools, on which we may say we have as yet no settled policy, and on which many of us are seeking further light and argument, it would seem to be our duty to patiently devote ourselves to their solutions and to contribute to the discussions whenever we feel that we can add a helpful word.

Respectfully submitted,

J. B. Johnson, *Secretary.*

Report of the Treasurer.

The Treasurer of the Society begs leave to report as follows for the year 1894–1895:

The total receipts during the year have been $661.13, the expenditures $566.06, leaving a balance in favor of the Society of $95.07.

The Treasurer deems it his duty to point out that the annual dues of $2.00 will not in the future be sufficient to pay the current expenses of the Society. During the year just passed, 80 new members were added and these, in addition to the annual fee of $2.00, paid each their initiation fee of $3.00. This is the reason why the Treasurer is in position to report a balance in favor of the Society. However, it is impossible to have such an increase in the membership in the future; consequently in order that the Society shall be able to pay its expenses, it will be necessary to raise the annual dues. The

Treasurer recommends that these dues be raised from $2.00 to $3.00 a-year, which raise, he thinks, will be sufficient for some time to come.

Thirteen dollars have been paid into the Treasury for fees not yet due. To compensate for this some members have not yet paid their dues for the year just closing, and also for the year before. The total amount of these dues is $76.00, of which amount $30.00 cannot be collected.

Eight dollars is due from one member of the Society for 150 extra copies of his paper read at the Brooklyn meeting.

A condensed statement of expenditures and income is attached to this report.

Respectfully submitted,

STORM BULL, *Treasurer.*

Statement of the Treasurer of the Society for the Promotion of Engineering Education for the year 1894–1895 :

INCOME.

Balance on hand August 20, 1894	$13.81
Initiation fees	244.00
Annual dues	294.00
From sale of Vols. I. and II.	109.32
Total	$661.13

EXPENDITURES.

Postage	$82.21
Stationery and typewriting	20.15
Printing of Vol. II.	301.00
Printing of circulars, etc.	135.30
Freight and expressage	15.90
Badges (Brooklyn)	10.00
Exchange on checks	1.50
Total	$566.06
Balance on hand September 1, 1895	95.07
	$661.13

STORM BULL, *Treasurer.*

REPORT OF THE AUDITING COMMITTEE.

THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.
SPRINGFIELD, MASS.,
Sept. 3, 1895.

We have this day examined the accounts of the Treasurer of this Society and find them to be correct.

JOHN J. FLATHER,
ALBERT KINGSBURY,
Auditing Committee.

ADDRESS BY THE PRESIDENT.

PROFESSOR GEORGE F. SWAIN.

The Society for the Promotion of Engineering Education meets to-day to hold its third annual convention, and rarely, I believe, has a society within the brief time of two years sprung into such vigorous, healthy existence, or attained such wide-spread influence. When our organization was effected in Chicago, but two years ago, there were in attendance 70 teachers of engineering, who at the close of that convention enrolled themselves upon the lists of the Society. This was, comparatively, a large number with which to begin our work; yet so rapid has been our growth, that within one year our numbers had increased to 156, and at the present time there are before us 28 applications for membership.

Our numbers must naturally always be much smaller than those of the great professional or educational societies, since our field is more limited; but in view of our rapid growth during the past two years, we certainly have reason to hope that within a short time we shall not only have represented among us every school in the United States and Canada which teaches engineering or any of the technical professions, but that every teacher of prominence in the country who is working in these lines will be enrolled upon our list of members.

This rapid growth shows conclusively that the Society has a mission—that it fills a need hitherto unsupplied; and we may well pause a moment, at this time, to consider what the objects of the Society are, and what results it may be expected to accomplish.

The first and most important object of the Society appears to me to be to enhance the reputation and influence, and even to formulate more definitely the existence of the profession to which we belong—the profession of *engineering teaching.* It is sometimes lost sight of, I think, that this is a profession at all. In the case of the classics, or in pure science, the fact is recognized—though not so generally as we could wish—that teaching is in itself a profession; but in the case of applied science, especially, it is too often assumed that the successful or experienced practitioner will necessarily be the successful instructor, and that teachers in these branches have little or nothing to do with questions of pure pedagogics. Unfortunately, it is only too true that professors in technical colleges have hitherto, as a rule, manifested little interest in questions of the science of education. In fact, we have, I think, made the mistake of considering our work as a branch of engineering, and of looking upon ourselves—not as educators—but as engineers or other practitioners, engaged for the moment, or for a portion of our time, in teaching.

The principles governing the teaching of applied science must be in general the same as those governing the teaching of other branches. Details, of course, may be different, but all educators, of whatever grade, must have much in common professionally, and must stand upon the same foundation. Yet few of us, I am sure, have felt that our professional place was in the various organizations of teachers, or that it was our professional duty to attend educational conventions, or to study and discuss matters relating to the theory of teaching. Many of us are members of one or more engineering or other technical associations; I wonder how many of us, before this Society was organized, were members of any educational association, or how many of us realized the advantage of coöperation with other teachers—such as those in the preparatory schools, upon whom we depend to give the student the training preparatory to our work, and with whose work our own must be closely connected.

This condition of things is, in my opinion, extremely unfortunate; and it has had the distinct tendency to lower the standing and to detract from the influence of the profession of teaching. No other profession, in comparison with the importance and value of its work—to the public, to the coming generation and to the State—is so poorly paid; in no other profession will men of equal ability work for such small material recompense. The fault is partly with the public, partly with our technical brethren, partly with ourselves. We have been ashamed to come out in our true colors, to stand for what we really are. We have in a measure deceived ourselves, our students and the public. It matters not if things are just as bad in other institutions, it matters not if doctors and lawyers do not study the science of education—it is only so much the worse for their teaching.

We should recognize, and we should force others to recognize, that in *engineering education*, the important—the controlling—factor is *education*, not *engineering;*

and if we wish to attain the truest success, we should seek to make ourselves first of all teachers, then engineers or practitioners to as great an extent as circumstances will permit; not primarily practitioners and secondarily teachers.

If we neglect to recognize these principles we run the risk, notwithstanding our vastly greater facilities and our labor-saving methods, of making our educational work less substantial and permanent than that of our predecessors, many of whom, while in no sense engineers, were most excellent teachers, to whom their students owe a greater debt of gratitude than they have ever realized.

There is a tendency in our technical schools—a tendency very difficult to resist in these days of applied science, and when competition is not limited to commercial enterprises—a tendency to subordinate the educational element to the engineering element—a tendency to make the school partake more of the character of an engineering establishment and less of the character of a purely educational institution. There is a great temptation to treat the students as though they came to us with minds already trained to think accurately and correctly; whereas, on the contrary, we all know that the principal work which we ought to do in any of our engineering schools is to teach the student habits and methods of thought, to teach him how to use his tools by drilling him upon principles rather than instructing him in matters of practice and detail; to make thinkers, not engineers. Some of us are trying to cover too much ground, to give the student more than he can master, because he has not yet learned thoroughly how to use his mental apparatus.

The tendency to which I have referred—toward engineering at the expense of education—is apparent to me in various ways. It shows itself, for instance, when a laboratory is used to carry out commercial tests with the aid of the students, or when it is conducted, not with the simple purpose of illustrating principles and of teaching students how to use apparatus and conduct tests, but for the purpose of carrying on elaborate investigations involving much repetition of the same operation; it shows itself in the increasing use of courses of lectures or single lectures by outside practicing engineers, a limited number of which are useful as lending interest to the subject and imparting enthusiasm to the students, but which in themselves may have, and, I think, frequently do have, little or no educational value, though, perhaps, great engineering value; it shows itself sometimes in the character of graduating theses, which are chosen, not so as to be of the greatest benefit to the student, but to solve some problem which the instructor desires investigated, or to cover ground which the student is not properly capable of covering; and it shows itself sometimes in the selection of teachers of engineering and other branches of applied science, not with regard to reference or ability in teaching—often entirely independent of this, and sometimes without reference to thoroughness of training—but on the basis of skill or experience in practice.

Let me not be misunderstood as disparaging the value of practical experience to the teacher of engineering. On the contrary, I believe that every such teacher should have had some practice, not necessarily a large amount, but certainly enough to develop fully what may be called the practical and economic sense. A teacher of applied science, like any other teacher, must, of course, first of all know what he is to teach—though knowledge to an extent far beyond the limits of the instruction given is not necessary to good teaching; but applied science differs from many other branches in that a thorough knowledge cannot be gained from books alone, but requires a practical familiarity with materials, instruments and methods. Neither should I be understood as saying that a good practitioner will never make a good teacher, which, of course, no one would assert. But I believe that the habit of mind involved in the practice of engineering or other applied science is very different from that required in teaching; and long experience in practice is, in my opinion, likely to be detrimental rather than conducive to success in education.

The young man who desires to devote himself to the teaching of engineering should therefore avoid a too long apprenticeship in practice, but should rather aim to continue a certain amount of practice along with his teaching, for in this way will he best keep in touch with engineers and with the practice of the day, and avoid falling into a rut. Moreover, he will be able to lend more variety and interest to his instruction, and will be more respected by his students. In the present condition of the teaching profession, it is no doubt sometimes necessary for a man fresh from practice to be put in charge of a department of instruction; but I trust that the time is coming when the quality of teachers—especially younger teachers—in our technical colleges will be such, and when moreover the appreciation of the value of education in engineering, and the desire to attain the truest and highest success on the part of those in charge of these institutions will be such—that a young man who, in the right way and with the proper preparation, devotes himself to the teaching of engineering as a profession will feel himself securely in the line of promotion to any position for which his natural abilities qualify him, and will not fear that after years spent in teaching he is likely to be superseded by a man fresh from the shop or the field. If engineering teaching is a profession, as I believe it is, there is no more inherent reason why a man should jump in at the top than there is in the law, or in medicine, or in any kind of business; and, if he does, it will involve a similar loss of time while he is adjusting himself and learning his new profession, besides being accompanied by a similar uncertainty as to whether, after he has learned it, he will be successful in it. And it must be emphasized that the success of a teacher, like that of a school, is not measured, in its truest and highest sense, by the number of students which he is able to attract, or by the completeness of the equipment which he is able to devise, but by the quality of his instruction, the real benefit derived by the students, and the changes wrought in their minds, which constitute the raw material upon which the teacher works.

And it is worthy of remark, that in other professional schools—of law and of medicine—where it has generally been the custom for the professors to be active practitioners, there has been in recent years, if I mistake not, some change of feeling, and a growing recognition of the fact that the best instruction may be given by men who are not and have never been in active practice, but whose time has been devoted to research and study. These schools, however, are not properly comparable, in many respects, with colleges of engineering.

The tendency to attribute overmuch importance to engineering practice in the education of the student is due, I think, in the first place to mistaken notions on the part of students and parents, who deceive themselves with the idea that a technical college can make a finished engineer, particularly if its teachers are practicing engineers; and who are attracted by anything of a practical nature. It is further due, I think, partly to the influence of practical engineers, many of whom, strangely enough, even though eminent, seem to be among those least capable of appreciating the importance of the educational element. After being in practice for some years, they realize that there are many facts, methods and details, which they did not learn in the college, and which they have been obliged to discover by experience—sometimes by costly experience—and because these have been of service to them, while some of the principles of the calculus have never been applied directly in their practice, they fail to realize the importance of the latter, not only as a means of mental discipline, but as a means of arriving at results of practical importance. We seem to recognize readily the elements which have been lacking in our training, while at the same time we may fail to recognize more important elements which have contributed to our success. Our deficiencies force themselves upon our notice every day, while our acquirements seem matters of course. We long for the things that we do not possess, and fail to realize what we have. For this reason, doubtless, men who have attained eminence in engineering, without having had the benefit of a thorough technical training, have proved, as a rule, in my own experience, sounder in their appreciation of matters of technical education than technical graduates. It is only by teaching, however, by watching and studying the development of the mind of a child or boy, that the proper perspective can be gained, and the relative value of the different elements in education determined.

I believe that in some of our technical colleges there is too great a tendency to defer to the ideas of practicing engineers rather than to those of teachers. For my part, I frequently hear suggestions from practicing engineers as to courses and methods which every experienced engineering teacher would know to be unwise and perhaps impracticable; and the assurance with which these suggestions are made, shows clearly that the speakers fail utterly to recognize that experience in teaching may be necessary before coming to definite conclusions on such matters. The difficulty is that these men are thinking about engineering, not about education. Their opinions on matters of education may have no more claim to serious consideration than my own opinions as to the law.

It is suggestive, in this connection, to contrast our colleges at the present day with their laboratories, their large force of teachers, and their great facilities in every line, and those of twenty-five years ago, with poorly equipped laboratories or none at all, and with few instructors, and those frequently pure mathematicians or theorists, with no experience or standing as engineers or practitioners. We may well ask ourselves whether the success, the usefulness, the rapidity of advancement of the graduates are *proportionately* greater to-day than in the past? I sometimes feel that the true answer may be in the negative, and that we may be using our greater facilities, not to save time, not to enable more training and a broader foundation to be given in the same time as formerly; but as ends in themselves, as means of teaching much that can better be learned elsewhere and later, or as means of carrying up the educational superstructure higher upon the same foundation, or, perhaps, even upon a narrower foundation than heretofore. Most of the middle-aged engineers and engineering teachers of to-day had no academic training in hydraulic, steam, or testing laboratories, and no instruction at all to be compared in extent to what is now offered in many of our schools, yet they have been able to bring our industries and our schools to their present high state of development. They did have, however, a training in those principles equipped with which any man of character, perseverance and average ability is bound to succeed, and without which no smattering of engineering details and practice, or of laboratory methods, will bring a man success of the highest kind. In these days, when science is advancing so rapidly that we know not what the morrow may bring forth, it is more than ever important, as our educational facilities are increased, first of all to broaden the foundation, then to carry up the superstructure higher.

My plea, then, is for the teacher, and it appears to me, as I have already stated, that the principal object of this Society is to increase among engineering teachers an interest in questions of pure education and to compel a recognition abroad of the profession to which we belong. In the furtherance of this object, and that we may better qualify ourselves for our work, we meet each year to consider means and methods of instruction and all the pedagogical questions involved in teaching applied science. Let us not forget that we are here to discuss education, not engineering. By learning from each other and keeping informed of what others are doing, we may not unreasonably hope to raise gradually the whole standard of technical instruction and to effect still greater economies of time.

By united action, too, we may effect some modifications in standards, although it does not seem to me that it is our proper function to do much in this direction. Engineering societies may adopt and bring into acceptance standard dimensions and rules, but education offers few opportunities of this kind, while individuality in teaching and in institutions is to be encouraged and not discouraged. Probably the most promising field open to our Society in this direction is in regard to entrance requirements, and we may perhaps hope to exert a favorable influence upon preparatory schools, in securing more thorough and uniform training than is now offered to students preparing for technical colleges. Possibly we may also secure a greater approach to uniformity in the entrance requirements of the technical colleges themselves. The Committee on Entrance Requirements, appointed at our last meeting, has since that time done a large amount of work, and will present a report of progress at this meeting, to which I invite your closest attention. The work to be done in this direction cannot be done in one year, and the Committee should have ample time given it to do all that it finds reasonable to accomplish.

Let us, then, enter upon the work of the Society with zeal and energy, feeling that it represents our chosen profession, for the advancement of which, material as well as otherwise, our best efforts should be given.

Library
N. C. State College

ENTRANCE REQUIREMENTS FOR ENGINEERING COLLEGES.

REPORT OF THE SPECIAL COMMITTEE.

To the Society for the Promotion of Engineering Education:

Your Committee on Entrance Requirements, appointed at the Brooklyn meeting, presents the following report:

The Committee, after consultation by correspondence, issued two circulars (see page 34) asking for certain facts and expressions of opinion on certain matters. One of these circulars was sent to the president of every college in the United States and Canada known as offering instruction in engineering of some form and grade, the desire being to obtain information at first hand in regard to entrance requirements and the college policy concerning them. When no replies were received within a reasonable time, duplicate circulars were sent to some instructor of engineering at the institution. Up to the present time, 55 out of over 100 colleges that teach engineering have sent in replies.

The other circulars were sent to the principals of about 500 preparatory schools, high schools, academies and manual training schools, situated in all parts of the country, which had been selected as typical schools by either a president or professor of a college located in the same district and drawing students from them. Thus far 148 replies to these circulars have been received. The details connected with the issuance of the circulars and the collection of replies, together with matters of correspondence, have been cared for by Dr. H. W. Tyler, the Secretary of the Committee.

During the summer, the college material collected has been studied by the chairman of the committee, and the material from preparatory schools has been worked over by Prof. J. P. Jackson.

The requirements for admission to 109 colleges teaching engineering in some form have been tabulated in detail from catalogues and the circulars, the colleges being grouped in five divisions by states, viz: Canada and New England, the Eastern, the Central, the Western and the Southern States. The States comprising the first group are those of New England and all of Canada. Those of the Eastern group are New York, Pennsylvania, New Jersey and Delaware. Those of the Central group are Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa and Missouri. Those of the Western group are the Dakotas, Nebraska, Kansas, Texas, Montana, Wyoming, Nevada, Idaho, Utah, Colorado, Arizona, California, Oregon and Washington. Those of the Southern group are Maryland, Virginia, West Virginia, Kentucky, Tennessee, Arkansas, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi and Louisana. Another tabulation shows the different subjects required for entrance, with the number of colleges in each group making the requirement. The same matter is shown again in a slightly different and more condensed form. (See Table A on page 39.)

The fifty-five replies to circulars have also been tabulated in detail, with further tabulations under each head in condensed form. These replies are well distributed among the different geographical groups and the several grades of colleges, so that they are representative as far as they go. It is to be regretted, however, that a larger number of replies has not yet been received, and that some of those received are not more full and detailed.

The material so far collected, relates to two classes of questions, viz: questions of fact and those of opinion. Attention is called to some points connected with each of these. Out of 109 colleges, 13 publish no requirements, 9 of these being in the South, 26 per cent. of all colleges require evidence of good morals, 53 per cent. require some age qualification, ranging from 14 to 18 years as a minimum, with 18 per cent. requiring 15 years and 28 per cent. requiring 16 years. The New England, Eastern and Central States are strong in mathematical requirements, about 55 per cent. in each of these groups requiring algebra through quadratics and plane and solid geometry, or more; while in the West and South, only 24 per cent. and 4 per cent. respectively, require the same amount. The Central States are much stronger in science requirements than the other groups, especially when the opportunities offered to candidates by way of options are considered; 14 colleges require an average of over 3 science subjects, while 7 colleges offer additional options averaging over 3. In advanced English requirements, the New England and Eastern colleges are strongest with percentages of 63 and 70 respectively, with the Central, Western and Southern groups following, with 55 per cent., 44 per cent. and 24 per cent., respectively, requiring such work. In foreign language requirements the Central group is the strongest, with the Eastern group a good second, followed by New England, the West and the South. Note that drawing is required by only 10 per cent. of all the colleges and that the larger part of these are in the Central or Western States.

An innovation appears in the requirement of one year's manual training by the University of Nebraska; and one year's practice in engineering, manufacturing or architecture, by the School of Practical Science at Toronto. The latter, however, affects only a small number of students who enter short of full matriculation. Note, also, that in three colleges (Princeton, University of Missouri and University of California), a failure in mathematics excludes a candidate from entrance, while at Cornell, University of Nebraska and University of Texas, a failure in English acts as a similar bar.

As would be expected from the newness of the country or its condition of non-development, the larger number of colleges with low grade requirements are found in the South and West. There is evidence here, however, of rapid growth and development, while there are a few colleges in each of the groups that will rank with the best of other groups as to requirements.

There are some changes going on in the requirements, as indicated by the catalogue announcements. The most marked is in English, the tendency being away from formal grammar and toward securing a better use of language and some knowledge of literature. The New England requirements are appearing in many of the college publications. They have been adopted entirely or substantially by seven colleges in New England, by five colleges each in the eastern and central groups, and by one each in the western and southern groups, with indications of further extension. Many colleges use part of the New England requirements. This furnishes a good illustration of the influence of inter-collegiate action when based on a felt want.

In mathematics, the tendency is to require algebra through quadratics and plane and solid geometry, and some of the catalogues of '94 and '95 announce changes in accordance with this.

In foreign language work, colleges announce either an addition or an increase of requirement.

Little change is announced in History, Science or Drawing.

What has gone before is based on a study of the latest issues of catalogues of 109 colleges and is practically complete. What follows is based on the 55 replies to our circulars to colleges and must be taken as incomplete, though representative as far as it goes. As to conditions, 3 colleges report no regulations; 2 say that none are allowed; 6 allow one condition; 5 allow two conditions; 9 allow three conditions; 7 say that the number allowed is variable with each case; 2 allow some indefinite number; 3 allow some indefinite number to be made up in the preparatory department; 5 allow none in Mathematics; 5 none in English; 1 none in Physics; 2 allow conditions in modern language only; 1 allows conditions not exceeding six periods of work per week. The practice of our colleges concerning the removal of conditions is as various as the above. Five colleges require them to be removed within three months; 4 within one-half year; 10 within one year; 1 within two years; 1 as soon as possible; 4 before matriculation is allowed; 2 allow them to be removed by good class standing; 1 requires examination as soon as the candidate is reported ready by an approved tutor; 1 requires them to be removed at once, *i. e.* before advanced work is taken. (See Table B on page 40.)

An attached tabulation will show in condensed form the extent of the practice of admission by certificate, and opinions as to its working and its extension by inter-collegiate action. (See Table C.) The replies under this head show that while the practice is quite various, nearly all of the correspondents are satisfied with their own plan. Those who receive on certificate are as well satisfied as those that accept on examination only. The number of reports is not sufficient to draw general conclusions. Yet there appears on the face of the returns, a leaning in New England, the Eastern and the Southern States, toward the examination plan, in the latter cases due to a lack of proper secondary schools and in the former cases to the age, traditions, strength and prestige of the stronger colleges. In the Central and Western States, the development of the State Universities as parts of State systems, with relations to the secondary schools sometimes regulated by law, gives to nearly all colleges in those sections a strong tendency to the certificate plan. Such dissatisfaction with the method as has been expressed, seems to come from a too free use of the system without proper restrictions. Correspondents from such points want restriction rather than extension, and believe that inter-collegiate action would help them to that end. These are included with the avowed opponents of the certificate plan, under the head of "no extension desired" in the tabulation. Some of the replies indicate that such help as can be given by inter-collegiate action is very much desired in regulating admission by certificate, while others either see danger in extension or desire it only to a limited extent. It is somewhat significant, however, that out of 55 colleges, 34 should report the plan of accepting certificates as practiced by them as more or less satisfactory.

No attempt has been made at a comparative study of the rules governing the acceptance of certificates. The incomplete returns and the meagre statements made in many cases, would make such a comparison of little value at the present time. Some of the colleges seem to have no rules, acting according to the faculty judgment in each case as it comes up. Some accept students on the certificate of the principal of the preparatory school to the extent of the ground covered, be it much or little, while others require the completion of an entire course. With some the presentation of the diploma is sufficient, while others require a detailed certificate from the principal showing the text used, the time given and the ground covered for each subject, and further certifying to the completion of a course of study, and expressing a favorable opinion as to the proper preparation of the candidate for admission. Very few of the colleges reporting, have clear, definite statements of their methods of commissioning or accrediting schools and their rules for maintaining the relation.

The opinions received on the matters of uniformity of requirements, considerations causing changes in requirements, the assistance that can be given preparatory schools by engineering colleges, and the changes desired in entrance requirements, are shown in abstract by the attached tables. (See tables D., E., F. and G.) 22 correspondents think uniformity desirable, while 10 consider it not desirable. 7 think it practicable, 10 practicable to a limited extent, 16 impracticable, while 5 deem it of little or no importance.

Forty-two per cent. of those reporting are governed by the condition of the preparatory schools in making changes, including about 50 per cent. of those in the Central, Western and Southern States.

The changes in requirements that seem to be the most largely desired, are advances in Mathematics, the addition of some science, mainly Physics and Chemistry, more or better work in English, and the addition of some work in foreign language, chiefly French or German.

The material received from the preparatory schools, about 150 in number, has been tabulated in detail, but owing to its amount and the lack of sufficient time for its thorough study, no condensed statements have been made concerning the existing courses of study. Of the replies to the circulars, about one-third came from New England. From some parts of the country the replies are not numerous enough to be thoroughly representative. The circulars from the preparatory schools are more full and satisfactory than those received from the colleges. The opinions expressed indicate something of a general law, while the replies from the colleges are often scattering.

Of the schools reporting, 70 per cent. do not advise any additional preparation before the student enters the technical college, while 25 per cent. do so advise.

In New England and the Eastern States, the larger number of schools feel able to advance their courses of study to some degree, while in the other groups the larger number say that they can make no advance. The advisability of such an advance is expressed by the larger number of schools in the New England group only. Seventy-one per cent. of all the schools consider that uniformity of college requirements, or their assimilation, would be of aid to them, 6 per cent. consider that this would be of no assistance, while 14 per cent. are satisfied with present conditions. Thirty-six per cent. of school correspondents think that the certificate plan should be extended, 13 per cent. that it should be extended with caution, 30 per cent. that it should not be extended (nearly all opposed to the system), 5 per cent. think extension immaterial, while 1 per cent. advocate a combination of certification and examination.

The replies to the school circular are shown in a condensed form in an attached table. (See Table H).

Your committee regrets the necessity of presenting this incomplete and unsatisfactory report. Various causes have contributed to the situation; the busy professional life of each of its members; our inability to get together for consultation and the necessity of arranging all matters by correspondence; our not beginning our work until about January 1st, for which the chairman assumes the responsibility; the gaps in the returns to our circulars; and last, but not least, the absence of Dr. Tyler in Europe for the summer. It is but just to the latter to say that he offered to resign his place on the committee, but we were not willing to lose his service and counsel.

The committee has purposely refrained from doing more at this time than to present the facts so far obtained, and in view of the importance of the matters entrusted to it, asks to be continued in its somewhat arduous duties for another year, if the Society so desires, so that the subject may be given the attention and study that it merits.

Respectfully submitted,

F. O. Marvin,
Mansfield Merriman,
J. J. Flather,
J. P. Jackson,
H. W. Tyler.

CIRCULARS SENT TO COLLEGES.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

COMMITTEE ON ENTRANCE REQUIREMENTS.

Boston, April 1, 1895.

Dear Sir: At the last annual meeting of the Society for the Promotion of Engineering Education (which now includes members of seventy-eight engineering colleges, or departments), a special committee was appointed to examine the general subject of Entrance Requirements, and report at the next annual meeting of the Society. As the report of the

Committee of Ten and other causes have attracted much attention to this important subject, and as the interests of scientific schools should be carefully considered in the general revision of preparatory school programs which is likely to ensue, it is the desire of the committee to obtain full information in reply to the appended questions.

The committee hopes to make the results of its investigations of general use by publication in the Proceedings of the Society, and respectfully urges that your answers be made as complete as possible. Very truly yours,

F. O. MARVIN,
Professor of Civil Engineering, University of Kansas.
MANSFIELD MERRIMAN,
Professor of Civil Engineering, Lehigh University.
J. J. FLATHER,
Professor of Mechanical Engineering, Purdue University.
J. P. JACKSON,
Professor of Electrical Engineering, Pennsylvania State College.
H. W. TYLER,
Secretary, Massachusetts Institute of Technology.
Committee.

NOTE.—This circular is sent to the head of each school or college known to give instruction in engineering. Where such instruction is not the main function of the institution, replies should be given for the department rather than for the school as a whole.

Please send replies to this circular to
H. W. TYLER, *Massachusetts Institute of Technology, Boston, Mass.*

I. *Present Entrance requirements.* In addition to the catalogue, copies of examination papers actually used are desired, also a general statement as to number of conditions allowed and regulations governing their removal.

II. *Changes of requirements.* (*a*) What (educational) considerations guide the college in making or not making changes?

(*b*) In what direction and to what extent are changes desired or desirable?

III. *Uniformity of requirements.* To what extent is it desirable and practicable that the requirements for admission to differerent engineering colleges be assimilated, *i.e.*, in the sense that requirements in a given subject should be identical in kind, but not necessarily in extent?

IV. *Preparatory Schools.* What assistance, if any, can be rendered to preparatory schools by the engineering colleges—for example, by coöperative action?

V. *Admission by certificate.* (*a*) To what extent does this replace examinations?

(*b*) What are the present rules for such admission and what latitude is allowed in their execution? (Detailed information is desired.)

(*c*) Is the operation of the system satisfactory?

(*d*) Is it susceptible of further extension—for example, by intercollegiate action?

VI. As a complementary circular is to be sent to a large number of representative preparatory schools, it is requested that the authorities of each engineering college receiving this circular coöperate with the committee by appending a list of (say 20) schools, public or private, in the State in question, selecting not the best, but those which shall be as fairly representative as possible of the general standards.

Name of college. (Signature and title of officer reporting.)
Date.

CIRCULAR SENT TO SELECTED PREPARATORY SCHOOLS.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

COMMITTEE ON ENTRANCE REQUIREMENTS

Boston, April 1, 1895.

Dear Sir: At the recent annual meeting of the Society for the Promotion of Engineering Education (which now includes members of seventy-eight engineering colleges, or departments), a special committee was appointed to examine the general subject of Entrance Requirements, and report at the next annual meeting of the Society. As the report of the Committee of Ten and other causes have attracted much attention to this important subject, and as it is of the utmost consequence that colleges and preparatory schools should coöperate cordially and intelligently, the Committee earnestly hopes that you will give it the fullest possible information in reply to the appended questions.

It may be added that the Committee regards preparation for scientific or other colleges as an essentially secondary function of the great body of high schools of the country; and believes that entrance requirements should be, so far as necessary, adapted to the capacity of any high school of thorough methods and high standards.

The Committee hopes to make the results of this investigation of general use by publication in the Proceedings of the Society, with a view to promoting "closer articulation" between the secondary school and the college, and will be grateful for your assistance and suggestions.

F. O. MARVIN,
Professor of Civil Engineering, University of Kansas.
MANSFIELD MERRIMAN,
Professor of Civil Engineering, Lehigh University.
J. J. FLATHER,
Professor of Mechanical Engineering, Purdue University.
J. P. JACKSON,
Professor of Electrical Engineering, Pennsylvania State College.
H. W. TYLER,
Secretary, Massachusetts Institute of Technology.
Committee.

Please send replies of this circular to
H. W. TYLER, *Massachusetts Institute of Technology, Boston, Mass.*

I. What are your present facilities for preparing students for admission to engineering colleges (or to any particular engineering college) in Mathematics, English, History, Foreign (including ancient and modern) Languages, Natural and Physical Science (with or without laboratory instruction), and Shopwork and Drawing? Statements as to ground covered, time given to the different subjects, *particularly mathematics*, material equipment in the way of apparatus, laboratories, shops, etc., are desired.

II. (*a*) What is the length of your preparatory course or courses? and what the average age of your graduates?

(*b*) Do you advise your graduates to devote additional time to preparation before entering an engineering college?

III. (*a*) What advance in requirements (if any) would it be practicable for you to meet?

(*b*) Do you consider such an advance desirable?

IV. To what extent would it assist you if engineering schools should make their requirements more nearly uniform? *i. e.*, in the sense that requirements in a given subject should, *so far as they go*, cover the same ground for all engineering colleges requiring them at all.

V. Do you desire or recommend an extension (or the reverse) of the system of admission by certificate?

NOTE.—Copies of your high school or academic courses of study will be acceptable.

Name of School. (Signature and Title of Officer reporting.)
Date.

TABLE A.

REQUIREMENTS FOR ADMISSION TO ENGINEERING COURSES IN 109 COLLEGES. SUBJECTS AND NUMBER OF COLLEGES REQUIRING EACH. (CATALOGUES OF 1894–95.)

(CONDENSED TABULATION.)

SUBJECTS.	Canada and New England 16 Colleges.			Eastern States. 20 Colleges.			Central States. 23 Colleges.			Western States. 25 Colleges.			Southern States. 25 Colleges.			Totals. 109 Colleges.		
	Requiring.	Not Requiring.	Giving Options	Requiring.	Not Requiring.	Giving Options	Requiring.	Not Requiring.	Giving Options	Requiring.	Not Requiring.	Giving Options	Not Requiring.	Requiring.	Giving Options	Requiring.	Not Requiring.	Giving Options
No Published Requirements	...	1	...	...	...	...	...	1	...	...	2	...	...	9	...	...	13	...
Evidence of Morals.	6	10	...	13	7	...	7	16	...	6	19	...	6	19	...	38	71	...
Qualification of Age	4	12	...	12	8	...	14	9	...	14	11	...	14	11	...	58	51	...
Writing	...	16	...	...	20	...	1	22	...	6	19	...	1	24	...	8	101	...
Reading	...	16	...	1	19	...	1	22	...	6	19	...	1	24	...	9	100	...
Spelling	1	15	...	5	15	...	3	20	..	8	17	...	2	23	...	19	90	...
Geography	7	9	...	13	7	1	11	12	...	14	11	...	12	13	1	57	52	2
Mathematics	...	...	...	...	...	...	...	1	...	...	2	...	...	8	...	...	11	...
Arithmetic only	1	...	...	...	...	...	...	...	...	5	...	...	3	...	...	9	...	...
Elem. Alg., no Geom	...	...	...	1	...	...	4	...	...	5	...	...	6	...	...	16	...	...
" " and Plane Geom.	6	...	...	9	...	...	4	...	...	7	...	...	7	...	...	33	...	...
Alg., Plane and Solid Geom.	5	...	...	6	...	...	11	...	...	6	...	...	1	...	...	29	...	...
Alg., Geom., and Plane Trig.	2	...	...	4	...	...	3	...	...	...	...	...	...	...	...	9	...	...
Alg., Geom., Pl. and Sph. Trig.	1	...	...	1	...	...	...	...	1	...	...	...	...	...	...	2	...	1
Higher Mathematics	1	...	...	...	...	...	...	...	...	...	...	...	1	...	...	2	...	...
Drawing	1	15	...	2	18	...	3	20	2	4	21	2	1	24	...	11	98	4
Manual Training or Practice	1	...	...	...	...	...	...	...	...	1	...	..	...	...	...	2	...	...
History.	...	4	...	...	1	...	...	4	...	...	13	...	...	11	...	...	33	...
1 subject only	8	...	...	14	...	...	11	...	2	10	...	5	8	...	1	51	...	8
2 subjects	3	...	...	5	...	...	6	...	...	2	...	...	6	...	...	22	...	...
3 "	1	...	...	...	...	...	2	...	...	...	...	...	...	...	...	3	...	...
Civil Government	...	16	...	2	18	...	5	18	3	2	23	...	1	24	...	10	99	3
Science	...	9	...	...	6	...	...	9	...	...	17	...	...	20	...	...	61	...
1 subject only	1	...	...	5	...	...	2	...	...	1	...	...	2	...	...	11	...	...
2 subjects	5	...	...	6	...	...	3	...	2	3	...	...	1	...	1	18	...	3
3 "	...	...	...	3	...	...	4	...	2	2	...	...	2	...	...	11	...	2
4 "	...	...	...	...	...	...	3	...	1	2	...	1	...	...	...	5	...	2
5 "	1	...	...	...	...	...	1	...	1	...	...	2	...	...	...	2	...	3
6 "	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1	...	...
8 "	...	...	...	...	...	...	1	...	1	...	...	...	...	...	...	1	...	1
English	...	1	...	...	...	...	...	2	...	...	2	...	...	8	...	...	13	...
Grammar only	2	...	...	3	...	...	3	...	...	9	...	...	4	...	...	21	...	...
Grammar and Composition	3	...	...	3	...	...	6	...	...	3	...	...	7	...	...	22	...	...
Advanced English	10	...	...	14	...	...	12	...	3	11	...	3	6	...	...	53	...	6
N. E. Requirem'ts (or nearly)	7	...	...	5	...	...	5	...	...	1	...	...	1	...	...	19	...	...
Foreign Language	...	8	...	...	9	...	...	11	...	...	20	...	...	23	...	...	71	...
1 year's work	3	...	...	5	...	...	1	...	2	...	...	...	1	...	...	10	...	2
2 " "	5	...	...	4	...	...	9	...	3	2	...	...	...	...	...	20	...	3
3 " "	...	...	...	...	...	...	1	...	2	2	...	...	1	...	...	4	...	2
4 " "	...	...	...	2	...	...	1	...	...	...	...	...	...	...	...	3	...	...
6 " "	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	1	...	...
English failure a bar to admis'n.	...	...	...	1	...	...	...	...	...	2	...	...	...	...	...	3	...	...
Mathem. " " "	...	...	...	1	...	...	1	...	...	1	...	...	...	...	...	3	...	...

TABLE B.

CONDITIONS. ABSTRACT OF REPLIES TO COLLEGE CIRCULARS.

(CONDENSED TABULATION.)

	Canada and New Eng. 10 Replies.	Eastern States. 9 Replies.	Central States. 15 Replies.	Western States. 11 Replies.	Southern States. 10 Replies.	Totals. 55 Replies.
No regulations (so reporting)	......	2	1	......	......	3
No conditions allowed	......	......	......	......	2	2
1 condition allowed	......	2	1	1	2	6
2 conditions allowed	1	......	2	1	1	5
3 conditions allowed	1	2	4	2	......	9
Number variable with each case	2	2	3	......	......	7
Indefinite number	......	......	......	......	2	2
Indefinite number to be made up in Prep. Dept.	......	......	1	2	......	3
No condition allowed in Mathematics	......	3	......	2	......	5
No condition allowed in English	......	2	......	2	1	5
Not allowed in Physics	......	......	......	1	......	1
Allowed in Modern Languages	......	1	1	......	......	2
Six periods of work per week allowed	......	1	......	......	......	1
Conditions to be removed—						
within three months	1	1	2	1	......	5
within a half year	......	2	1	......	1	4
within one year	4	1	1	3	1	10
within two years	1	......	......	......	......	1
as soon as possible	......	1	......	......	.. ...	1
before matriculation	1	......	1	2	......	4
by good class standing	1	......	......	......	1	2
by exam. when reported ready by tutor	......	1	......	......	......	1
before advanced work is taken	......	......	1	......	......	1

TABLE C.

ADMISSION BY CERTIFICATE.
ABSTRACT OF REPLIES TO COLLEGE CIRCULARS.

(CONDENSED TABULATION.)

	Canada and New Eng. 10 Replies.	Eastern States. 9 Replies.	Central States. 15 Replies.	Western States. 11 Replies.	Southern States. 10 Replies.	Totals. 55 Replies.
Present extent, to a large amount	2	2	9	5	......	18
to a moderate amount	1	3	1	1	......	6
to a limited amount	1	......	......	1	2	4
to some undefined amount	1	1	5	1	3	11
certificates not taken	3	3	......	2	3	11
Certificate plan, satisfactory	5	4	7	5	3	24
partially satisfactory	......	1	5	2	2	10
not satisfactory	......	1	1	......	......	2
susceptible of extension	3	1	7	2	3	16
only within State lines	......	......	1	......	......	
only to a degree and with caution	1	4	1	......	1	7
no extension desired	1	1	3	3	2	10
no answer concerning extension	4	3	3	7	4	21

TABLE D.

UNIFORMITY OF REQUIREMENTS.
ABSTRACT OF REPLIES TO COLLEGE CIRCULARS.

(CONDENSED TABULATION.)

	Canada and New Eng.	Eastern States.	Central States.	Western States.	Southern States.	Totals.
Uniformity, desirable	5	4	8	2	3	22
not desirable	1	4	4	1	......	10
practicable	1	3	2	1	......	7
practicable to a limited extent	1	......	3	2	4	10
not practicable	3	3	4	5	1	16
of little or no importance	......	......	......	1	4	5

TABLE E.

CONSIDERATIONS CAUSING CHANGES IN REQUIREMENTS. ABSTRACT OF REPLIES TO COLLEGE CIRCULARS.

(CONDENSED TABULATION.)

	Canada and New Eng. 10 Replies.	Eastern States. 9 Replies.	Central States. 15 Replies.	Western States. 11 Replies.	Southern States. 10 Replies.	Totals. 55 Replies.
Requirements of other college departments	1	......	......	......	......	1
State law	1	......	1	1	1	4
Condition of preparatory schools	2	3	8	5	5	23
Changes in other colleges	......	1	1	......	......	2
Progress in engineering practice	......	1	......	......	......	1
Educational value of studies	......	......	......	1	......	1
Ideal needs and present possibilities	......	......	......	1	......	1
Conditions due to the civil war	......	......	......	......	1	1
Acquisition of general literary education before admission	1	2	......	......	......	3
Improvement in preparation of students	1	2	......	......	......	3
Improvement in preparation in mathematics	......	1	......	......	......	1
Elevation of state standards	......	1	......	......	......	1
Maintenance of a high standard	2	......	......	......	......	2
Gain of time for technical studies	......	2	......	......	1	3
Desire to make courses as wholes reach to the senior year of Cornell	......	......	1	......	......	1
Conferences with State teachers' association	......	......	1	......	......	1
Aid in securing positions for graduates	......	......	......	1	......	1
Establishment of a state system of united schools and colleges	......	......	......	......	1	1
Necessity of taking the material offering	......	......	......	......	2	2
Policy of the college not to change	1	......	1	......	......	2

Table F.

ASSISTANCE THAT CAN BE GIVEN PREPARATORY SCHOOLS BY ENGINEERING COLLEGES. ABSTRACT OF REPLIES TO COLLEGE CIRCULARS.

(CONDENSED TABULATION.)

	Canada and New Eng. 10 Replies.	Eastern States. 9 Replies.	Central States. 15 Replies.	Western States. 11 Replies.	Southern States. 10 Replies.	Totals. 55 Replies.
By raising requirements	2	3	......	......	......	5
adopting uniform requirements	3	1	3	1	......	8
influencing them to do thorough work	1	1	2	......	......	4
suggestions and help as to work and methods	......	1	......	2	2	5
insisting that applicants for admission should have completed a school course	......	1	......	......	......	1
working through State Board of Education	......	......	1	......	......	1
admitting by certificate from accredited schools	......	......	3	......	1	4
"Much in every way"	......	......	......	......	1	1
"What?"	......	......	......	1	......	1
Can render no assistance	......	......	......	......	3	3

TABLE G.

CHANGES DESIRED IN REQUIREMENTS FOR ADMISSION. ABSTRACT OF REPLIES TO COLLEGE CIRCULARS.

(CONDENSED TABULATION.)

	Canada and New Eng. 10 Replies.	Eastern States. 9 Replies.	Central States. 15 Replies.	Western States. 11 Replies.	Southern States. 10 Replies.	Totals. 55 Replies.
None		3	1			4
Better preparation in spelling, writing, composition		1				1
Transfer of time from elementary branches to Latin, French and Drawing	1					1
Gradual elevation of standard		1			2	3
An elective system					1	1
Requirements as heavy as for classical course			1			1
Two years of college work as a foundation	2					2
Making requirements equal to those obtainable in towns of 8000		1				1
Manual training school work as a foundation		1				1
Better preparatory instruction			1	2		3
Mathematics: Algebra		1	1	1	1	4
Advanced Algebra			2	1	1	4
Plane Geometry			3	2		5
Solid Geometry		1	2		1	4
Trigonometry	1		2			3
Analytical Geometry			1		1	2
elementary Mechanics	2					2
advance or better work	1	1	1	2	1	6
Drawing, or better work in Drawing			2	1	1	4
English: better work			2	3	1	6
advanced work	2	1	3	1		7
more work	1	1	2		1	5
Science: Physics	3		1	1		5
laboratory work in Physics				1		1
more work in Physics	2					2
Chemistry	2			1		3
Physical Geography				1		1
more work				1	1	2
History: United States			1			1
England				1		1
Civil Government				1		1
more work		1				1
Foreign Language: French				1	1	2
French *or* German	2		2		1	5
French *and* German		1	1	1		3
1 year of Mod. Language				1		1
German *or* Latin			1			1
2 years of Latin	1					1
Less Latin			1			1
Omission of Latin	1					1
Better work			1			1

TABLE H.

CONDENSED TABULATION OF 148 REPLIES TO CIRCULARS SENT TO PREPARATORY SCHOOLS.

	New England. 52 Replies.	Eastern States. 28 Replies.	Central States. 27 Replies.	Western States. 31 Replies.	Southern States. 10 Repies.	Totals. 148 Replies.
Advise additional preparation	14	6	7	8	2	37
Do not advise additional preparation	34	26	19	19	5	103
Can advance courses by some varying amount.	32	17	11	11	4	75
Cannot make any advance in courses	17	9	14	15	6	61
Consider advance in course desirable	27	9	11	7	5	59
Consider advance in course not desirable	13	13	10	15	3	54
Consider uniformity in requirements an aid	36	21	20	21	7	105
Consider uniformity in requirements of no assistance	2	......	3	1	......	6
Satisfied with present conditions	11	3	2	5	......	21
Desire extension of certificate plan	19	10	14	15	6	64
Do not desire extension of certificate plan	25	5	5	7	2	44
Desire extension with caution	5	7	3	3	1	19
Think extension immaterial	1	2	2	2	......	7
Desire a combination of examination and certification	1	1	......	......	......	2

DISCUSSION.

PROF. MANSFIELD MERRIMAN called the attention of the Society to the use of the word "college" as distinguished from the word "school," in the report. It was thought that the word school, as applied to institutions for teaching engineering, might sometimes be misunderstood, and, therefore, the word college has been used, except for the preparatory school. He thought that if all were to use, universally, this word "college," instead of "school," to say technical colleges instead of technical schools, it would tend to place engineering education on a higher plane in the estimation of the public. In the report the word school had been used only for preparatory institutions.

PROF. FRANCIS R. FAVA, JR., called attention to one or two difficulties under which they had labored at Columbian University. They found it really necessary to lower their entrance requirements, not because they feared competition, but because they were losing good material among men who had insufficient preparation. This was in 1885. This lowering continued, but now the pendulum is swinging back the other way. They are now making the requirements higher, and arranging for a preparatory course of one year. However, when they lowered the standard it was not their fault; they were compelled to it by circumstances.

PROF. JOHN B. JOHNSON asked the gentleman to explain a little more in detail the circumstances by which they were so "compelled."

PROF. FAVA replied that the situation was peculiar. There were a number of men in government service who were good men, who had more or less time on their hands, and who wished to complete their education if they could. The courses were given partly in the evening. A great many of these men were not prepared to pass the entrance examinations, but were quite willing to take extra courses in mathematics; in fact, they were willing to do everything possible in order to enter and complete the course. The requirements were therefore lowered to make it possible for them to enter. The standard has since been raised, and many predicted a speedy falling off in attendance, but the fact that they were wise in adopting the course taken, is evidenced by a largely increased attendance. Another source from which they draw is the Washington High School—a very good institution, but which has been leaning to the academic side, so that a great many of the men were insufficiently prepared in mathematics. The standard had to be lowered to reach them. The High School has raised its standard, so that this obstacle is not now in the way, and Columbian University has raised its standard also.

PROF. CARL L. MEES thought one point was often lost sight of, and that was what is meant really by "standard of admission?" Does it mean that if the student is said to be "prepared" in plane and solid geometry, he has really a better preparation than if his time had been given entirely to plane geometry? There is a difference between an intensive and an extensive study of mathematics, and in many cases better preparation will be gained by insisting upon a better text, better teaching and more time for the more elementary subject, than by including solid geometry and trigonometry. When it comes, for instance, to solid geometry, most of the work will have to be done in a technical school anyway. He did not believe that the rank and file of teachers in preparatory schools could do that work well. It would have to be reviewed at any rate. In fact, it would be necessary to review nearly every thing required for admission. The question is whether the effort should be in the direction of specifying higher topics for entrance or in trying to get better work in the preliminary subjects?

Prof. Storm Bull did not think that the last speaker had stated the case correctly. The University of Wisconsin required a certain amount of time spent on each subject. Their experience was that solid geometry had been well taught in the high schools; algebra not so well. More time, therefore, was now being required to be spent on algebra. He thought that it ought to be insisted upon that the entrance requirements are really fulfilled.

Prof. J. Galbraith wished to make a few explanations with regard to the requirements for admission in the School of Practical Science, Toronto. In the Province of Ontario all the universities had a common standard of admission. The examinations determining admission were held once a year by the Provincial Department of Education.

Students were admitted to the School of Practical Science on presenting certificates that they had passed the above examinations. The subjects required for matriculation are Latin, English, History, Mathematics, French or German and either (1) Greek or (2) the second modern language with Physics and Chemistry. Students were also admitted who had passed in all the above subjects except Latin, or who had passed in all except Greek, in which case the subjects under (2) were obligatory.

As the school is a provincial institution it was felt desirable to provide in some way for the admission of men whose occupations were more or less connected with engineering work, but who might find it impossible to return to the high school in order to work up all the subjects required for admission; an examination in English and Mathematics is accordingly provided for such candidates, and in lieu of the remaining subjects required of the high school graduates, they have to present certificates of having had at least one year's employment in practical work. Not more than half a dozen candidates have been admitted per year up to the present time under these provisions. There has been no reason to regret the admission of such candidates, as they are usually faithful workers.

Prof. William G. Raymond agreed with the last speaker that in special cases where men of business who were earning their living were also endeavoring to get an education, some encouragement should be offered.

THE SCOPE OF AN ENGINEERING COLLEGE.

BY WILLIAM G. RAYMOND.

Professor of Geodesy and Road Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

What is the proper scope of an engineering college? Should it include work now generally left to the so-called preparatory schools, and if so, to what extent? Should it include also post-graduate work, and if so, what work?

This subject must refer to what might be called an ideal engineering college, for it is morally certain that many of the colleges of engineering now established will not, even should this convention decide it to be best, introduce what they are pleased to call preparatory studies into their curriculums, though they may and probably will, if, indeed, they have not already done so, add post-graduate work. The writer is not sure that he knows what is meant by preparatory work, nor what by post-graduate work. In each individual college such subjects or parts of subjects as must be completed by a boy to meet the reqirements for admission to the college constitute, it is assumed, preparatory work; and any work done by him in advance or in excess of that required for the degree of the college may be considered post-graduate work if it is done after graduation. It is difficult to discuss in general the question as it reads; for what is undergraduate work for one college is preparatory work for another, and is post-graduate work for still another; and each college must decide for itself according to its peculiar circumstances where it will begin and where end its work. Let the question be stated in another form, a form in which the writer recognizes a subject on which he has, at least, opinions.

What is an engineer? What should a young man know, to entitle him to be called an engineer? What should he know, to be called a specialist? How much of this knowledge can he acquire in school? What portion of this knowlege is it practicable to offer in *one* school? What portion is it desirable to offer in one school?

The treatment of this subject must necessarily be general and brief. To go into detail would be to cover the ground of each of the papers that are to follow.

Within a few months we have had the engineer variously and frequently defined. For the purposes of this paper he will be defined to be "One who uses the laws, forces and materials of nature in the design and execution of works, including structures and machines." This definition, it is believed, includes everything except that special branch of military engineering relating to the conduct of operations of war.

It will be assumed as granted that every man, be he doctor, lawyer, merchant or chief engineer, should acquire all the general information possible; that every man, either before or while securing the special training necessary to fit him for his chosen vocation, should acquire a thorough knowledge of his own language and literature, of history and social science. It will also be assumed as admitted that this culture training should, if possible, be acquired before taking up the special bread and butter subjects.

In addition to this general education for all men, the engineer must, to fit himself for his special calling, be first well versed in the laws, forces and materials of nature, not omitting the human element. Second, he must be familiar with the application of these laws, forces and materials, so far as already developed, in the construction and operation of works. Third, he must understand the practical details, prices, ordinary tools and methods, possibilities of animals, machines and men ; in a word, he must have experience.

When he has acquired a certain fraction of the whole knowledge in each of these lines, the size of which fraction will be left to the other speakers on this program to determine, the young man is fit to be called an engineer.

Before he can take up the first of these three divisions of special learning, he must possess a certain tool or kit of tools called mathematics.

When the young man has acquired the proper fraction of each of the divisions already named and has in addition acquired about all there is known of a special branch of one, as bridge and building construction, railway construction and operation, electrical theory and practice, he is fit to be called a specialist; as a bridge engineer, railway engineer, electrical engineer, etc.

The writer believes it will be admitted that all of the knowledge mentioned, with the exception of experience and the knowledge of how to handle men, may be obtained in a school or schools. The latter acquirement comes only to those who have the faculty, to be developed by experience, inborn. That is to say, the use of the tool mathematics, and various hand tools, and the knowledge of physical science, mechanics and materials, to be obtained from books and in a laboratory by experiment, may be acquired in the school. We know this is true because we have separate schools whose combined curriculums include all this matter.

I think it will also be admitted that it is possible so to organize and equip a single college that it may offer the entire list of subjects; for this would be indeed but combining what is to-day known as the manual training school with the best engineering college, and modifying and adjusting the scheme of study in each so that together they shall form one harmonious, consecutive whole. It will doubtless be admitted that a building or series of buildings, a teaching force and laboratory plant, could be brought together under one management to form a single college that could offer theoretical and practical instruction, so far as it is practicable to offer it in a college, from what may be called the very beginning of special study to the highest class of theoretical and experimental investigation.

It will, no doubt, be further admitted that such a college is not only possible, but entirely practicable. Indeed the writer is familiar with one institution that approaches very near to this suggested college, and that holds a high place among the engineering colleges of the land. Among the various schools comprising Washington University, St Louis, are the Manual Training School and the Polytechnic School. These two have entirely independent courses, each complete in itself, and all that is lacking to make them one is an arrangement of studies that shall give one closely consecutive course. While not prepared to say that they are mutually helpful, the writer does know that the Manual Training School has been and is of great value to the Polytechnic School, and in all probability the Polytechnic School is in turn of some help to the Manual Training School.

The writer feels pretty sure that up to this point he has said little that will excite discussion or that will appear to any of us other than well-known or almost self-evident facts. But when he tries to give his views on the last question to be considered, namely, what portion of this training is it *desirable* to offer the young engineer in *one* school or college, he fears that he will find himself almost, if not quite, alone. The writer has given this matter a good deal of thought during the past year and has arrived at conclusions that are believed to be at variance with the opinions of educators generally, and particularly with those of the teachers in the higher institutions of learning. These conclusions are offered with the conviction that they are right.

It is the writer's belief that with the growth of knowledge we are putting too much of mathematics and science on the preparatory schools and beginning too far along in our colleges. He believes that geometry, except mensuration as given in arithmetic, and algebra, except the solution of simple equations, have no place in a high-school course. They are purely special studies preparatory to the pursuit of further special investigation.

Those subjects having to do with the thoughts and acts of men are of far more service to the average man of business, to all men except engineers, than are geometry, algebra, or indeed any mathematics beyond arithmetic.

The public schools of secondary grade should be modeled to give the best service to the greatest number of the youth to be served. The great mass of boys and girls drop out of school at the close of the grammar grade, and the majority of those who remain to attend the high school close their school life with their graduation from this institution. It is the few who go further to college, and but a portion of these to scientific pursuits.

The ideal high-school course, if there can be an ideal course, is, in the writer's opinion, one that gives its greatest strength to language, literature, history and social science, and adds the simple facts of physical science without theory, or indeed omits them entirely. Such a course could be arranged to give to its graduates more of what may be called the culture studies than is now usually given to the graduate of the engineering college.

The great fault found to-day with our educational work in general is lack of thoroughness in English language and literature. There is an attempt to cover too many fields, resulting in thoroughness in none.

The writer's position is this: The engineering college, and other colleges as well, may profitably lower their requirements for admission in mathematics and raise them in language and literature, history and sociology, compelling the preparatory schools to meet the changed requirements. To this extent at least, it is believed, all engineering colleges may profitably extend their work to include that of the so-called preparatory schools. Really this is hardly an extension, but an exchange. An exchange of so much humanity for so many tools.

The writer knows what the tendency might be if this were done. It is easy to say of the applicant for admission, "He has passed in the subjects essential to his progress here and failed in his language. It would be a hardship to exclude him; we will enter him with conditions." This is wrong. That it is unnecessary is evidenced by the fact that certain of our State Universities, with comparatively severe entrance requirements in English, provide that a signal failure in this subject will exclude the applicant from any of the scientific courses, and the provision is carried out faithfully. It may perhaps be said that it is easier to accomplish in a public school than in a private school, but this is at least doubtful.

The limit that has been mentioned is as far as the writer believes it well to go downward with the work of the engineering college, except in the matter of tool instruction. As to the value of tool instruction nothing will be said, for I could add nothing to the volumes that have been written on this subject. This one word may be said—that no school in this country that offers a course in manual training is able to find room for all who desire to enter. It at least fills a supposed want. The writer believes that the engineering college can well reach downward—if indeed it is down—to the extent of providing a course in hand work with machinists' and builders' tools and materials.

A mistake that is constantly made, is to put too young a man on inspection work. A course in handling tools and materials will be of great service to him in this work, and of great service to his employer as well.

Strictly the engineering college has nothing to do with these preparatory subjects, for it must not be forgotten that the engineering college is a professional school. If this is kept carefully in mind it should be evident that such subjects as do not pertain to engineering have no place in its curriculum; or, to go a step further, it may be said that only the subject of engineering (this is here considered one subject with many branches) has a place in the curriculum of an engineering college.

Our engineering colleges of to-day are a mixture of preparatory school and professional school, just why it is not apparent. It is the only professional course so combined with a general college course leading to a bachelor's degree.

The writer believes it to be well on many accounts, chiefly because of the resulting economy of educational energy and a more systematic and complete arrangement of studies thus made possible, to continue this combination, and to go a step farther to include so much as has been mentioned of what is now usually called preparatory work. In saying that culture studies have no place in an engineering college, the writer will not exclude them from what is called later the preparatory department.

On the other hand, how far shall the engineering college extend its courses upward? It seems to the writer that the limit is not short of the limit of human knowledge of engineering subjects and the possibilities of laboratory investigation.

It is to the college laboratories that we must look for the means of carrying on almost all experimental research that can be best done in a laboratory. The Pennsylvania Railroad maintains a laboratory and, while the world at large profits to some extent by this, the laboratory is for the use of the Railroad. Several great manufacturing concerns maintain well-equipped experimental laboratories. These are of some use to the world of engineers, but they are mainly for the use of those who sustain them. The college laboratories should be thrown open to the use of all reputable persons competent to use them. This does not mean that the use should be free; but here should be the place where the engineer desirous of pursuing some certain lines of investigation may come for a reasonable consideration to do his work. This does not mean either that an engineer who has some tests to make in the line of his business should be furnished at small cost a plant for the purpose. The laboratory should be open for experimental investigations for the development of general physical laws and for general tests of materials only.

The libraries of the engineering colleges should be as complete as possible and open to the use of the public under well-considered restrictions. The writer believes what he has said, to be particularly true of the engineering colleges of State Universities.

As to just where the dividing line between undergraduate and post-graduate work should be drawn, there will be a diversity of opinion. It is the writer's belief that the boy who has completed such a course in mathematics as is usually given in our engineering colleges, a thorough course in general physics, a similar course in chemistry, geology, mineralogy, rational mechanics and astronomy, is, with the understanding that sufficient training in language, literature and social science has been obtained from some source, eligible to the degree of Bachelor of Science or its equivalent. It is believed that special work in the application of these sciences to engineering should be classed as post-graduate work and should lead to a professional degree, just what will not be specified.

It is unquestionably a fact to-day that the engineering students of our colleges do more and harder work for a degree of equal grade than do the students of other departments. The recent accessions to the store of knowledge of physical laws and forces and their applications have been so vast in extent that a time sufficient to do a quantity of work that shall entitle a young man to the degree of Bachelor of Arts or Bachelor of Letters, is not sufficient under our modern requirements to permit him to secure the equal grade of Bachelor of Science; and if the two degrees are given at the expiration of the same number of years of work it simply means that the two are not rewarded on the same basis of work performed. It is true in theory that it is not the degree that should be sought, but an education. Nevertheless, the degree is a certificate of work done, usually valued according to the college that gives it; and the degrees of equal grade in one college ought to represent approximately equal amounts of work performed.

The writer believes it is perfectly practicable and that it is desirable to incorporate into the curriculum of one college a training for engineers that shall begin with algebra, and shall include practice in the operations involved in the building arts that shall cover a complete course in the sciences fundamental to the study of engineering, and a theoretic course in the application of those sciences which may be properly called a course in engineering.

As already said, there is no limit short of the limit of knowledge in this direction. There should, however, be a limit set in each particular branch of the special work, beyond which it is undesirable to take the young man before turning him out to gain experience. Within this limit should be found the fundamental principles and a certain amount, that will not now be defined, of practical detail of each of the so-called branches of engineering. Specialization should come only after a thorough grounding in the general principles of all branches.

The college would consist, therefore, of what might be called two schools. I. The preparatory school, comprising a portion of what is now commonly called preparatory work and a portion of what is known as college undergraduate work, the course leading to a Bachelor's degree. II. The professional school, comprising a course in general engineering rather more extensive than is now usually given in any one course, leading to a professional degree, and a post-graduate professional course, leading to a Master's or Doctor's degree in the special department. It is to be expected that but a certain few of the whole number of students in attendance will take the special advanced work in any one department, and that the majority of students will go into practice at the conclusion of the general course.

Thus we have purely a special college for engineers, who must come to it prepared in language, literature and social science, which studies really have no place in a college of engineering. Students would, of course, come variously prepared in these subjects, and a certain minimum requirement for admission, higher than that now common, should be established. As already stated, it may be impracticable to exclude language and literature from this college, beginning, as it does, so far down the scale in mathematics and science; but the requirements for admission in these branches should be high, and the work in the college of a high grade but small in amount.

About a year ago the writer prepared, as a suggestion, a course in engineering that approximated to the ideas presented in this paper. Neither that nor a modified course is presented at this time, because it would be, to a great extent, anticipating the topics that are assigned to the succeeding speakers.

When the opinions of the several specialists who are to tell us what should be included in their particular departments are given us it will be easier (possibly) to arrange a complete course.

One institution made an attempt some years since to do very nearly what has been outlined in this paper, and the engineering course was made five years long, a Bachelor's degree being given at the end of four years and a professional degree a year later.

A single college can hardly make such an innovation as this, particularly if it is at all dependent upon tuition for support; but if all the engineering colleges of the country, including the strong State Universities, were to adopt this plan, or one that should be its equivalent, the writer believes it would result in no loss to the colleges and in great gain to the future engineers of our land.

DISCUSSION.

PROFESSOR C. FRANK ALLEN said he felt some hesitation in saying much about the views expressed in the paper just read, which was just the sort of thing that was wanted by the Society, inasmuch as it was very full of thought which had been developed in a direction quite new to most of those present, and certainly gave to all something to think about. Professor Raymond, as he stated, had been at work on this subject for a year, and the speaker felt that it was difficult for those who heard some of his views expressed for the first time to criticise them at short notice, and it hardly seemed proper that the speaker's remarks should be viewed in the light of criticism, but perhaps rather in the way of suggestion. One of the first things that impressed him was this: During the past few years he had been connected with the lower schools, and in high-school work had been particularly impressed with the effect upon the students of the instruction given them. During the first part of the time that he was a member of the school committee the instruction in the high school was of rather inferior quality; it shortly became very much better;

both language and mathematics were taught in excellent fashion, and the result upon the pupils was very marked. Whereas, in former years, the completion of the high-school course had marked the close of the scholar's education as a rule, under the improved work it does not mark the close of the scholar's formal education. A year ago 75 per cent. of the graduating class had determined to pursue their education further and were now carrying out their resolve. He believed their resolution was prompted by the fact that the superior education which they had received at the high school, gave them a taste of what might be attainable in the future, something that scholars in former years had not had. It seemed to the speaker that if the course that Professor Raymond has outlined was to prevail, at the close of the high-school course the scholars would have been educated neither for an academic, nor for a technical college, but for business alone, and that the incentive to continue work in certain higher directions would have been taken away. It therefore seemed that such a course would be to the advantage neither of the scholars nor of the schools. It looked as if the scholars would be left in such shape that they would not be provided with any incentive, but would be more or less at sea. It was difficult to understand how they could then determine whether they had any taste or ability for work in an engineering college or in any college, and in so far as they were prepared only for the business side, it seemed that serious disadvantage resulted.

Another point that occurred to the speaker was this: If the course outlined by Professor Raymond should be carried out, there was danger that there would be too much concentration of mind on one line of thought. Some of the most valued articles of food would not be to most people quite satisfactory for a steady diet, and it seemed possible that the introduction of language, political economy, or other studies that might serve as a relief from the distinctly engineering studies, would be wise as taking into account human nature. If Professor Raymond's paper was understood aright there would be no difficulty, in the manner in which his course would be arranged, in reference to the sequence of studies, starting as late as he did with his mathematics. That difficulty must be taken into account.

Mr. William Kent felt we ought to be greatly indebted to Professor Raymond for his paper, even if there had been no disagreement: but when a man brought ideas in this way he stimulated thought, though the speaker entirely disagreed with him. Henry George's books, for instance, were very interesting and most valuable, but the speaker thought them to be all wrong. So Professor Raymond's paper was very good, but he did not agree with him at all. The best thing in his paper was where he stated the fact that he was all alone in his opinions. As the speaker understands him, he would leave algebra and geometry out of the culture schools. The speaker thought this would be a criminal offence, to deprive a scholar of that insight into one of the greatest things in Nature, which is got by geometry. At the age of seventeen the speaker did not know just what he ought to make of himself; there was no incentive in any particular direction; what would have become of him was uncertain, but through some accident he was enabled to have a course in elementary civil engineering, and for the first time in his life the speaker saw the direction in which his future work might lie, and the whole of the field of engineering was opened to him. That opening which was presented in the high school was the starting point.

Every possible "window of the mind" should be opened so that when a boy gets to be seventeen or eighteen years of age he could have some idea of what course to follow. The trouble with the preparatory schools has been that they trained the youth only for business, and not very well for that; but now, when a boy was given some general science, physics, mathematics, etc., he would be capable of taking hold of anything. He had four years of Latin in his own course, three of those he thought wasted, as far as the time spent on Latin was concerned. The speaker had become a disbeliever in the classics, but his boy had just taken a year of Latin, geometry and algebra, and it had had the best possible effect on him. Latin enables a boy to give continued thought to a subject; algebra gives the power to accomplish something by dint of hard work and study; and geometry opens the world of astronomy, mechanics, etc., to the student. The training which comes from the study of these three subjects should be given in the preparatory schools. In regard to the engineering college, Professor Raymond claims that culture has no claim there. This was wrong, because many scholars of our engineering colleges had not obtained the necessary culture beforehand ; and men who were supposed to have had this training, after being carried through a four years' course without any general culture studies, find themselves badly handicapped by the lack of just those studies during the four years.

Professor John J. Flather was disposed to look upon mathematics as a study from which to obtain mental discipline, and partly as a kit of tools, as Professor Raymond had said. The great difficulty that we have met with in our technical colleges, and that can be noticed elsewhere, has been to get the student so that he will have the mastery of these tools at an early point in his course. There are certain subjects that he must study later on that demand the mastery of mathematics, and he must have that somewhere reasonably early in his course, so that he may take the other subjects that depend on that, in their proper sequence, and make way for other subjects still later ; if we were to keep this study out of the high school, and thus give the student his first taste of mathematics in his college course, we should not be preparing him sufficiently early. For some of our work, such as hydraulics, thermodynamics, higher machine design, etc., it would then come too late. A certain amount of time is necessary for each subject, and with mathematics it is not practicable to double up on the time, as it is with some other subjects ; that would be the trouble if we were to keep mathematics out of our preparatory schools.

Professor Francis R. Fava, Jr., invited attention to a practical exemplification of the system which Professor Raymond had brought to notice in his paper.

The speaker had experience with a preparatory course consisting of algebra, geometry, mechanical drawing, English literature, French, etc., containing the elements of mathematics and culture. Following this came a regular engineering course, then a post-graduate course. This was exactly the course, as regards the culture side of it, outlined by Professor Raymond. This plan had been working for the past few years, and they were now trying to get away from it. They were trying to make a change, and to get the mathematics out, and put them into what would then be called the preparatory year, and simply for the reason that has just been mentioned, that they find they were being crowded in the mathematics. It was found that the students were not sufficiently prepared when they got into the higher course.

Professor Dwight Porter stated that as regards his own daughters he was desirous that they should have a good training in geometry and algebra, feeling that girls who had finished their studies were often without the ability to reason closely, and to draw accurate conclusions, in which the above studies give excellent discipline. If this training were important for girls it was still more so for boys, and inasmuch as by many young people it could not be obtained at all if omitted from the high-school course, he believed that the studies should be retained there.

As concerns the placing of laboratories at the service of engineers for commercial experiments, he believed there would often be found serious practical objections to such a course, and that such work had better be in charge of officers of the school or college.

In so far as it could thus be undertaken without interference with regular class work it might be of material value.

Professor Frank O. Marvin believed in the first place that an engineer is just as much of a man as any other man; and if that was the case, if he was to hold the same position in society as other men hold, he must be prepared for it. There had been a time when an engineer was simply the tool of a man who had some money to expend; that time had now gone by, and to-day, if the engineer was to maintain himself in society at large, he must be rather broadly cultured, the more broadly the better. To his mind there were five lines of educational work; mathematics, language and literature, history, art, and general science. The man who lacked in any one of these lacked an element necessary to him, both as a man and as regards his contact with people at large. The preparatory or high school was the place where the first genuine tastes in those lines should be cultivated. It was the place where the first real impression was made, and where there was provided the most impressionable material. So, to his mind all these lines ought to find a place there; and furthermore, every engineering course ought to have some representation of each of them. It was a question, now, of what can be done.

The ideal would be to have this running through the preparatory, undergraduate and post-graduate courses. Of course ideals were not obtainable just now, and it was necessary to be content with the best possible under the circumstances that surround us. He always felt afraid of any movement toward concentration of the lines of action in our elementary education.

Professor Raymond writes in concluding the discussion: It seems necessary in concluding this discussion first to correct the impression that seems to have been produced by the paper, that the writer would educate boys first for business, and would make the high-school course a business course.

Nothing could be farther from his mind. He would make it preparatory to what is generally called an English college course, or, as it is called in one school, a course in Letters and Political Science. The plea is for more training in English and allied culture studies for students of applied science and for business men.

Professor Allen thinks that if the culture studies are omitted from the engineering course there will be danger of too much concentration of mind in one line of thought. The writer's experience is that he can do his best work in any one line when he can stick to the line, and not when scattering his energies in several different directions.

There is plenty of good reading to occupy the leisure hours of a student if he is inclined thereto. The engineer's work is not play, but it should be so nearly play to him who chooses it for his life work that it will need no admixture of sweetening ingredients.

The plea for a variety of studies in the lower schools is that the child may discover its natural bent, the field in which it loves to work. To the writer's mind there is danger in this in that it leads to too early specialization. He believes that this is not merely a supposed danger; it is real, and the effects of the evil are already apparent.

As to Mr. Kent's understanding that the writer would omit algebra and geometry from the culture schools, and all culture studies from the engineering college, a careful reading of the paper will, it is believed, disclose no such statement, at least so far as the first charge is concerned.

What is said is that only the elements of algebra and geometry should be taught in the public high school and that culture studies have no place in a purely engineering college. This does not mean that one school may not offer both courses in engineering and culture as all universities should do, but the work in engineering should be enough in itself to occupy the time of the average young man and should come after he has prepared himself in other lines to be a man. It means that the requirement in culture studies for admission to the engineering college or department should be raised and the college or department treated as a professional school.

An engineering college is a professional school just as much as is a medical school or a law school. and the course in business should follow. and not go along with culture training if the best results in both directions are to be obtained. Concentration is the universally admitted first requisite to good work in all lines except in school work. Why not here? We have become accustomed to a certain kind of engineering college and it seems impossible to lose sight of this in talking of the entirely different school outlined in this paper.

As to the idea that political economy might better be left to man's middle age, it may be said that we are never too old to learn, and within limits the older we are the more readily and fully we comprehend matters of this kind; but if the elements of political economy were properly taught in the lower schools more men would start with right ideas, and we as a nation would perhaps not be in the disgraceful position of continually reissuing pieces of paper that represent no value; precisely in effect what we condemn in the manipulators of Erie stock, but what we are willing to do with United States stock—if the writer may be allowed the expression.

As to a fancied difficulty in securing sufficient early preparation for advanced work if advanced algebra and geometry be left to the college course, the difficulty of considering the particular schools outlined in this paper apart from the school of to-day is again met. If the time devoted to culture studies in the engineering colleges was given to technical work there would be plenty of time for all work of this character.

It may seem surprising when it is realized, but it is true that the mathematics taught in the Rensselaer Polytechnic Institute, with a very moderate entrance requirement, requires for advance, review and examination, just a little less than forty-seven weeks. With not more than one secondary study to interrupt, this could all be done in very little more than one school year, and could certainly be finished with some advanced work at the end of the first half of the sophomore year.

Replying to Professor Porter, the writer can say that he too has a daughter and he hopes she will know something of algebra and geometry (and as she has a mother who made a better record in calculus than her father, it is probable that if she lives she will), but he is willing that she should wait till she gets to college to learn most of it; and if she is not to go to college there are other studies of more importance to her than these.

The writer agrees heartily with what Professor Marvin says that an engineer is, or ought to be, a man, and that he should be rather broadly cultured; and it is believed if the paper is read aright this fact will stand out clearly. But he does believe in concentration, particularly in the segregation of business from culture. One thing at a time and culture first.

Now all this discussion has turned on one point, and the real object of the paper lost sight of in the unimportant detail of whether or no algebra or geometry shall be taught in the public high school, a question purely of general educational policy and really foreign to the general topic under discussion, and one that should perhaps have found no mention in my paper.

The real object of the paper was to point out what the writer thoroughly believes, namely, that every student of engineering, every engineer, should be a graduate of a culture school of high grade, and the writer's course is developed with this idea in view, and with such modifications as seemed necessary to make it practicable to-day. It is moreover prepared from the standpoint of the private engineering school, and not from the standpoint of the universities with engineering departments, although many of the suggestions seem to apply equally well to them, and it is these same universities that are in the position to make the engineering colleges of the high grade outlined in the paper.

The writer has endeavored to point out, without saying it in so many words, that we can not do our best toward making a man and an engineer in the four years between 17 and 21 any more than we can do our best toward making a man and a lawyer, or a man and a doctor, or a man and a minister, in the same immature and limited period. The course that is outlined seems to be one step in advance toward what in the mind of the writer is sure to come, viz: the separation of the engineering college from the general undergraduate school, so that the connection shall be in the universities even only nominal, and so that a course in culture with a little technical work added, or a course in technical work with a little culture work added, shall neither of them be the ideal engineering school or course, but that the engineering college shall be a purely professional school, training men of high grade in their life work. The details and methods set forth may be faulty, but it is believed that the principle is right.

THE PRESENT REQUIREMENTS OF AMERICAN ENGINEERING COLLEGES IN NON-PROFESSIONAL STUDIES.

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Before taking up the subject of the introduction of non-professional studies into engineering courses, the writer has desired to learn the general opinion as well as practice, in this particular, of a number of the engineering educators of the United States. The replies which his inquiries have elicited are as varied as they are interesting, and form a valuable testimony to the timeliness of a consideration of this question. Further research has been made among the catalogues and schedules of the engineering institutions of the country. Those selected for comparison from among over a hundred, whose catalogues were examined, may be grouped as follows:

First, those where the work is purely technical, that is including in their curricula little more than studies which will be classed as indirectly and directly technical. These colleges assume that the student has already had a good general training, and is ready to enter upon a professional course pure and simple.

Second, those which though making the entrance requirement as high, in some cases higher, than the first group, continue general culture work in connection with the technical, throughout the whole or a part of the course, the argument in favor of this policy being that an engineer is better equipped for usefulness in his profession if a generous proportion of his hours of training have been devoted to the humanities.

Third, a smaller number, which present courses that are to a large degree elective, under conditions which admit of the student taking more or less of the general culture work according to his individual needs.

Though the line of division between the first and second groups is quite distinct, the expression of opinion gathered from those in positions of authority in the institutions under consideration is by no means so clearly defined; indeed, in some cases, the wisdom of the prevailing usage is questioned.

Some extracts from the letters received may prove suggestive. The following is from the president of a well-known technical college of the highest grade:

"The tendency of this institution is quite marked in the direction of eliminating general subjects from the technical courses. Though the feeling is quite unanimous that a broad general education is very desirable for engineers, the necessity of professional training makes it impossible to give much of this kind of work in a four years' course."

"Prescribed courses in general culture have been eliminated in the belief that all of the students' time is absolutely necessary in order to obtain a proper grounding in the essential scientific courses."

From another:

"There has been a tendency for some years back to increase the amount of technical work in the engineering courses at the expense of the non-technical or general culture work. We need more preparation in

English and general culture and are trying to attain a higher standard in entrance examinations. We cannot help the students after they are in to any great extent."

Quite decidedly opposed to these expressions are the following from the more liberal institutions of engineering. The first given is from a well-known college, of which the entrance requirements are among the highest, yet their candidates for graduation are required to take three years of language study, and also to devote a small amount of time during three years to studies in composition, literature, history, political science, etc.

"The demands of the technical departments are so great as to make it almost impossible to provide any additional time for culture studies;" and yet note that "at the same time the head of the engineering department has just now arranged for a special course in financial subjects, at the cost of time heretofore allotted to technical work; and the head of another department has repeatedly expressed the wish that he could find the opportunity to have an additional course of the same character given to his students." The tendency in another college of long established and excellent standing, is " decidedly towards giving increased weight to what may be termed general culture studies in connection with the engineering courses."

A considerable number of men at the head of engineering colleges express a similar belief to that of the president of a New England college, who writes, "My own conviction is that there must be a recoil from the tendency to excessive development of the technical side in education." The reaction which this opinion denotes, has undoubtedly taken its origin in large measure from the difficulty encountered by many institutions in raising the entrance requirements. In a number of states, the public school system is so inferior as to constitute a very unsatisfactory feeder to the college, which is compelled to make up for the deficiencies of the early education by including work in its curriculum which should properly belong in the high-school course. In these States, an advance in the admission requirements must wait upon an advance in the grade and quality of the public-school work, since few institutions, certainly no state institution, can afford to exclude all pupils except those trained in private preparatory schools. Those fortunate state institutions which have succeeded in articulating themselves with the public-school system by raising its standard, and not by lowering their own, are in a measure independent, but to many still struggling to attain this position, the problem of entrance requirement is, of course, a vital one in the consideration of the question of the amount of non-professional work to be introduced into engineering courses.

In this connection I desire to say that the catalogues of this year of the engineering colleges of the United States show progress in this particular. A large proportion of the institutions reviewed, noted either in the catalogue or an accompanying circular, a decided advance recently made. The agitation of this question which has taken place during the past few years has undoubtedly borne good fruit. Nevertheless, it is the rule that colleges of engineering must be satisfied to advance slowly toward the high standard which will be attained when the institution which to-day must be content to "recommend" that the applicant for admission be an academic college graduate shall require this to be the case. Much as it is to be desired that this day be early reached, the facts of the case as they *are* must be taken into consideration, and not as they should or will be. Colleges of the third group would seem to best meet the requirements of this case. An elective system, admitting of the student taking more or less culture work according to circumstances, if properly controlled, must attain the end of giving the opportunity to obtain the best possible education, in the broadest sense of the word. There are, however, but a small proportion of all the engineering colleges that adopt this system.

In order to show, comparatively, the amount of non-professional training the graduates from engineering colleges receive, the following table has been prepared:

(In this table the abbreviations are full enough to be readily understood, with, perhaps, one or two exceptions. F. is for French; G. for German; H. for History; Gr. for Grammar; Al. for Algebra, etc. For Eng. (English) the expression "New England requirement" has been used for convenience in all cases where the requirement is the same as, or very similar to, that which was adopted some time since in the New England colleges.)

Name of Institution.	Course.	General Culture.		Indirect Technical.		Technical Work in Course.	Per Cent. General Culture.	Per Cent. Indirect Technical.	Per Cent. Technical.
		Subjects Required for Admission.	Work in Course.	Subjects Required for Admission.	Work in Course.				
Massachusetts Institute of Technology.	M. E.	F. or G., Gr. and sight read'g; Eng., New Eng. requirements; U. S or Ancient H.	522	Al.: Plane Geo.; Adv. Al. or S. Geo.	719	1252	21	29	50
Worcester Polytechnic Institute.	M. E.	F. or G., Gr. and translation; Eng., New Eng. requirements; U. S. H.	505	Ar.; Al. (elements); Pl. Geo., S. Geo., Bks 7 and 8.	736	1687	17	25	58
University of Vermont.	M. E.	Eng., New Eng. requ'rments: Anc't and Modern Geography.	204	Ar.;Al.(thro'gh Qu. Eq.);Pl. and S.Geo.	683	1408	9	30	61
Tufts College.	M. E.	F. or G., Gr. and sight read'g; Eng., New Eng. requirements.	526	Ar.; Al. (through Qu. Eq.); Pl. and S. Geo.	703	1375	20	27	53
Maine State College.	M. E.	Eng., New Eng. requ'rments; U. S. H.; Polit'l and Phys. Geog, Physiology and Botany.	730	Ar.; Al. (elements); Pl. Geo.	660	1265	27	25	48
Brown University.	C. E.	F. or G., Gr. and sight read'g and simple conversation; Eng., New Eng. requirements.	454	Al. (through Eq. 2d degree); Pl. Geo.	686	1028	21	31	48
New Hampshire College.	M. E.	Eng., New Eng. requ'rments; American Hist.; Political and Physical Geog.; Physiology.	415	Ar.; Al. (to Quad.): Pl. Geo.	740	1100	18	33	49
Columbia College.	E. E.	F. and G., Gr. and sight read'g; Eng., New Eng. requirements; U. S. H.	0	Ar.; Al. (elements); Pl. S. & Sph.Geom.; Pl. Trig.; Physics; Ch'm., F.H.Dr'w'g.	637	2346	0	21	79
Cornell University.	C. E.	F. or G., Gr. and sight read'g; Eng., New Eng. requirem'ts; American H.; Political and Phys. Geog.; Physiol. & Hy.	275	Ar.; Al. (Elem'y & Adv.); Pl. & S. Geo.; Pl. & Sph. Trig.	499	1418	12	23	65
The Pennsylvania State College.	M. E.	Eng., New Eng. req'irments; U. S. H.; Phys. and Descriptive Geog.; Physiology.	580	Ar., Al. (thr'gh Qu.) Pl. Geo., Physics.	726	1709	19	24	57
Lehigh University.	M. E.	Eng., Gr., Rh., and Composition; U. S. H. and Constitution.	532	Ar.; Al.; Pl. Geo. 6 books Chauvenet; Element'y Phys.	512	1232	23	22	55
University of Pennsylvania.	M. E.	F., G., Gr. and Translation; Eng., New Eng. requirem'ts; U. S. and Ancient H.	378	Ar.; Al. (through Quad. Eq.); Pl. and S. Geo.; Pl. Trig.	816	1498	14	30	56
Swarthmore.	M. E.	F. and G., Elem'ts Gr., sight translat'ns or Lat. eq.; Eng., New Eng. requirements; U. S. H. & Eng. H. or Gen. Geog.	544 or 340	Ar.; Al. (thr'gh Eq. of 2d degree); Pl. Geo.	986	1088 or 1296	21 or 13	37	42 or 50

		General Culture.		Indirect Technical.					
Name of Institution.	Course.	Subjects Required for Admission.	Work in Course.	Subjects Required for Admission.	Work in Course.	Technical Work in Course.	Per Cent. General Culture.	Per Cent. Indirect Technical.	Per Cent. Technical.
Western University of Pennsylvania.	M. E.	G. or Lat. 1 year; Eng., Gr. and essay; U. S. H.; Phys. and Polit. Geog.; Physiology.	468	Ar.; Al. (to Quad); Pl. Geo.	748	1205	19	31	50
Ohio State University.	M. E.	Eng., New Eng. req'rements; U. S. H.; Geog. and two of fol.; Bot., Physiol., Civil Gov., Gen. H., Eng. Lit.	440	Ar.; Al. (elements); Pl. and S. Geo.; Physics.	742	1501	16	28	56
Rutgers College.	E. E.	Eng., New Eng. req'rements; U. S. H.; Phys. and Descrip. Geog.	936	Ar.; Al. (elements); Pl. and S. Geo.; Phys. and Chem'y.	600	1228	34	22	44
Lafayette College.	E. E.	Eng., New Eng. requirements; U. S. H.; Geog.	635	Ar.; Al. (thro' Rad. & Quad.); Pl. Geo.; Physics.	755	891	28	33	39
Case School of Applied Sc'nce.	M. E.	G. or F. or Math. (H. Al. and Pl. and Sph. Trig.); U. S. H.; Eng., New Eng. requirem'ts.	520	Ar.; Al. (Eq. of 2d degree); Pl. and S., Geo.; Phys. & Ch'm.	966	1317	18	35	47
Rose Polytechnic.	M. E.	Eng., Grammar; U. S. H.; Geography.	491	Ar.; Al. (through Quad.); Pl. Geo.	949	1388	17	33	50
Purdue University.	M. E.	Eng., Grammar; U. S. H.; Geography.	296	Ar.; Al. (through Quad.).	727	1628	11	27	62
University of Illinois.	M. E.	F. or G., Gr. and sight reading or Latin, 1 year. Eng. New Eng. requirements; Eng., U. S. and Gen'l H. and (*).	280	Al. (thro' Quad.); Pl. and. S. Geo.	672	1530	11	27	62
University of Michigan.	M. E.	F. or G., Gr. and sight reading or Lat. equiv.; Botany; Eng., New Eng. requirements; U. S. and Gen'l H. & (†).	408 or 510	Al. (thro' Quad.); Pl. and S. Geo.; Pl. Trig.; Phys.	527	1105 or 1003	20 or 26	26	54 or 48
University of Wisconsin.	M. E.	F. or G., Gr. and sight reading; Eng., New Eng. requirements; U. S. H.; Physiol. and Bot.; Adaptive Subjt., 2 years.	272	Ar.; Al. (thro' Rad.); P. and S. Geo.; Phys.	661	1963	9	23	68
University of Minnesota.	M. E.	G. or F., two years prep'n; Eng., two yrs. prep'n; U. S. and Anc. H.; Physiol. and Bot.	343	Al. (Elementary & Higher); Pl. and S. Geo.; Chem. and Phys.	745	1619	13	27	60
Washington University.	M. E.	F. or G., 2 yrs. or 1 yr. F. and G.; U. S. and Eng. H.; Eng. essay.	255	Al. (thro' Rad. and Eq. 2d deg.), Pl. and S. Geo.; F. H. and Geom. Dr'g; Chem.; Phys.	732	1836	9	26	65

* Any three of following: Astron., Bot., Chem., Phys., Physiol., Zoölogy, F. H. D. † Any two of following: Chem., Geol., Zoöl., Physiol., Phys., Phys. Geog., Astron.

Name of Institution.	Course.	General Culture.		Indirect Technical.		Technical Work in Course.	Per Cent. General Culture.	Per Cent. Indirect Technical.	Per Cent. Technical.
		Subjects Required for Admission.	Works in Course.	Subjects Required for Course.	Work in Course.				
University of Missouri.	M. E.	F., G. or Latin, 2 years; Eng., Gr., Comp'n & Rhet.; Gen. H.; Biology.	187	Al. (Element'y); Pl. Geo.; Chem. or Phys.	646	1428	8	29	63
University of Kansas.	E. E.	F. and G., 1 year each or Latin 3 years; Eng., New Eng. requirements: Physical Geog.; Gen'l H.; Civil Gov't.	442	Al. (thro' Quad. eq'ns); Pl. and S. Geo; Phys.	868	1646	15	29	56
University of Nebraska.	E. E.	F. or G., 1 year each; Eng., New Eng. re-requirements; U. S. and Gen'l H.; Physiol.; Botany.	224	Ar.; Al.; Pl. and S. Geo.; Chem.; Phys.; F. H. D.; Man'l work, 1 year.	888	1000	11	42	47
University of California.	M. E.	F., G., Lat. or Eng., 2 yrs.; Eng., New Eng. requirements; Gov't of U. S.; Physiol. or Botany.	0 or 36	Al. (thro' Quad.); Pl. Geo.; Phys.; Chem.; Min.; Pl. Trig. or F. H. D.	921	1256 or 1200	0 or 2	42	58 or 56
State University of Iowa.	E. E.	Four years' High Sch'l course or its equiv.	465	Four years' High School course or its equiv.	720	990	21	33	46
Michigan Agricultural College.	M. E.	Grammar; Reading; Spelling; Penmanship; U. S. H.; Geography.	506	Ar.; Al. (as far as Quad. Equations).	736	1687	17	25	58
Columbian University, Corcoran School of Science.	M. E.	No requirements specified in Catalogue.	324		902	1409	12	34	54
West Virginia University.	M. E.	Eng., Grammar; U. S. H.; Geog.	690	Ar.; Al. (through Coefficients); Pl. Geom.; F. H. D. or equiv.	500	1422	27	19	54
State College of Kentucky.	M. E.	Eng., Grammar; Geography.	365	Arithmetic.	847	2248	11	24	65
University of Tennessee.	M. E.	Eng., Gr. and essay; and any 2 of fol.: Geog. and U. S. H. or Phys. and Physiol. or Greek or Latin.	424	Ar.; Al. (to theory of expon.).	1096	1428	19	35	46
Vanderbilt University.	M. E.	(F. or G. to be requir'd 97.) Eng., New Eng. requirements; Amer. H.; Phys., and Polit. Geog.	610 or 444	Al. (Elementary); Pl. and S. Geo.; Mensuration.	873	1669 or 1835	19 or 14	28	53 or 58
Alabama Polytechnic Institute.	E. E.	Eng., G. and Composition; U. S. H.; Geog.	884	Ar.; Al. (to Quadratic Equations).	981	1459	27	29	44

This table gives not only the relative amounts of the different classes of work required in the thirty-seven institutions scheduled, but also their requirements for admission, similarly classified. This classification, it must be understood, is more or less arbitrary. It is impossible to draw a distinct line between one group of studies and another, and say, "This is purely cultural: this technical." Mathematics, which is classed as technical (indirectly), is universally accepted as affording the best possible mental discipline. On the other hand, language, which has been classed as a culture or non-professional study, unquestionably forms an essential element in the equipment of a successful engineer. The writer appreciates, therefore, that the hard and fast lines of the tabulation may convey a wrong impression, and has intentionally avoided the use of the words professional and non-professional in the classification, it being his conviction that there should be no such line of demarcation between the cultural and technical studies; they all are, within certain limits, properly classified as professional.

In the table, "Culture Work" includes Language, English Literature, History, Political Science, Botany, Physiology, etc.; "Indirect Technical" includes Pure Mathematics, Chemistry, Physics and other studies, which, though closely allied to the technical, are given in any good college course. The subjects included under "Technical" need not be enumerated. Data were collected in the beginning from all of the engineering courses given in each catalogue, but, as the numbers resulting from the grouping we have made differed but little, it seemed unnecessary to present the results from more than one course, and, wherever possible, the course in Mechanical Engineering was selected because the writer has a more detailed knowledge of what is being done in this department in the various institutions than in other departments. In those cases where the Electrical Engineering or Civil Engineering courses are given, the institution in question either gives no Mechanical Engineering course, or some feature of the catalogue made it impossible to obtain the information desired. In classifying the Civil Engineering and Electrical Engineering courses, certain modifications were made, the most important of which was the division of the work in Physics, in the Electrical Engineering course, between the indirectly and directly technical groups.

In summing up the amount of work in a course, the practical work in field, laboratory or shop, as compared to the recitation work, has been accredited according to the usage of each institution, the unit having been obtained either from the catalogue or from an officer of the college. The figures therefore represent credits rather than exercises or hours. As the unit of credit differs in different institutions (being two to one, or two and a-half to one, or three to one) this may at first sight seem an unequal basis of comparison, but it is fair to assume that all the institutions count upon occupying the full time of the student, and that the differences in the methods of accrediting practical and recitation work arise from a difference in the amounts of time accounted necessary in the preparation of the subjects assigned, an element which cannot be tabulated. This variation in credits accounts, in some measure, no doubt, for the variation in the figures which stand for the sum-total amounts of work of the different institutions.

In order to insure the correctness of these figures, a schedule was sent to each institution for correction before the figures were entered in the table. A large number of these schedules have been returned, with no important corrections, except in one or two special cases. It has, therefore, seemed safe to assume that the schedules not heard from, are sufficiently correct to afford a fair comparison. If errors have been made in interpretation, the same errors have been made in all; if any of these errors are important, the writer must beg to be exonerated. The figures were taken from the sources supplied by the institutions themselves, but the members of this organization need not be told that college catalogues are difficult to interpret.

In cases where elective hours are given which may be taken in either culture or technical work, two sets of figures appear in the table, one showing the division of time with the elective hours taken as culture work, the other giving them to the technical side. It is probable that in actual cases the elective hours are divided, but the figures as given represent the extreme possibilities, between which other adjustments would lie.

The facts have been gathered from all grades of institutions, the lower having been included for the reason that so many engineers are graduates from these colleges that no discussion pertaining to engineering education in this country is complete which does not recognize them.

From the table it will be seen that the amount of time devoted to culture work in the thirty-seven colleges presented ranges from zero per cent to 36 per cent. The average is 16½ per cent, or if the one institution which gives over 28 per cent is excluded, the average is 16 per cent. It is to be noted that it does not follow that those colleges which give the least time to culture work require the most for admission. Thus, of two of the leading colleges, the Massachusetts Institute of Technology and Columbia College, making essentially the same requirements for admission, one gives 21 per cent of its time to general culture work, while the other gives none; a third, making even higher admission requirements, gives 12 per cent to general culture.

Of the subjects included in the culture group, English and Language are the most widely given, all of the thirty-seven colleges including English, except the University of California and Columbia College, while the former presents elective hours which may be taken in English if desirable. Twenty-eight of these colleges give one or more modern languages. Of those courses which give no language, one is the Civil Engineering Course of Cornell University, the Mechanical Engineering Course of which does include a language. The University of California, Swarthmore College, University of Nebraska, and the Alabama Polytechnic Institute, give electives which may be taken in language study. Of these, the three first named require a language for admission. Purdue University and the University of Tennessee do not require language work either for admission or in the course.

Columbia College requires it for admission, but does not include it in the course.

Fifteen of the thirty-seven include Political Economy; among these are Cornell University, the Massachusetts Institute of Technology, Worcester Polytechnic Institute and The Pennsylvania State College. Twelve give History, their requirements for admission averaging fully as high as those of the colleges not including it. Ten give English Literature. Geology appears in the schedules of seven colleges; Constitutional Law in but six; Hygiene also in six; Ethics in four; Logic in two; International Law in but two. In one only, the Western University of Pennsylvania, Astronomy is included in the Mechanical Engineering course.

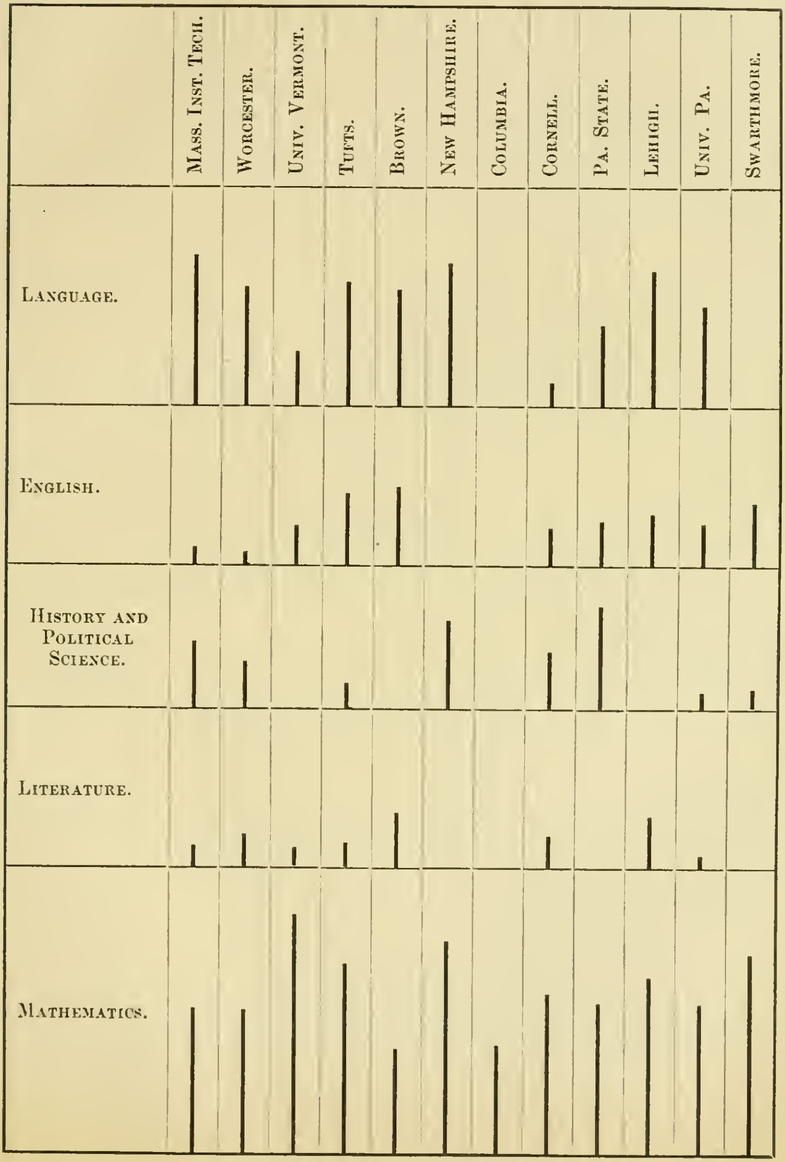
This is a brief resumé of the culture work given in a good number of our leading Engineering Colleges. It shows a striking want of uniformity even among institutions of the same grade. It is not the purpose of this paper to criticise, or enter into a comprehensive discussion of these conditions, but there is one conclusion that forces itself on the attention. This is, that considering the material they have to work upon, many of these institutions must be giving an incomplete, one-sided education to their students. It seems that, although it is unquestioned that the graduate in engineering should be equipped with the broad cultivation of a liberal education, yet it is the final decision of many colleges that time cannot be spared from work in technical lines to be devoted to general work. That this should be true in so large a number of cases is deeply to be deplored. Until the students can be drawn from among young men who have already completed a good general culture course, it seems essential that, in order to afford the best engineering training, a generous proportion of time be devoted to the humanities. Professor Burr's opinion on this point, expressed in his paper on "The Ideal Engineering Education," read at the Chicago meeting, may well be recalled. He says:

"There are few professional men to whom the broad cultivating influences of a liberal education are more needful than to the engineer. His early professional practice does not induce any development which can fill the voids of a faulty general education, while his later practice demands what only the liberal training can supply."

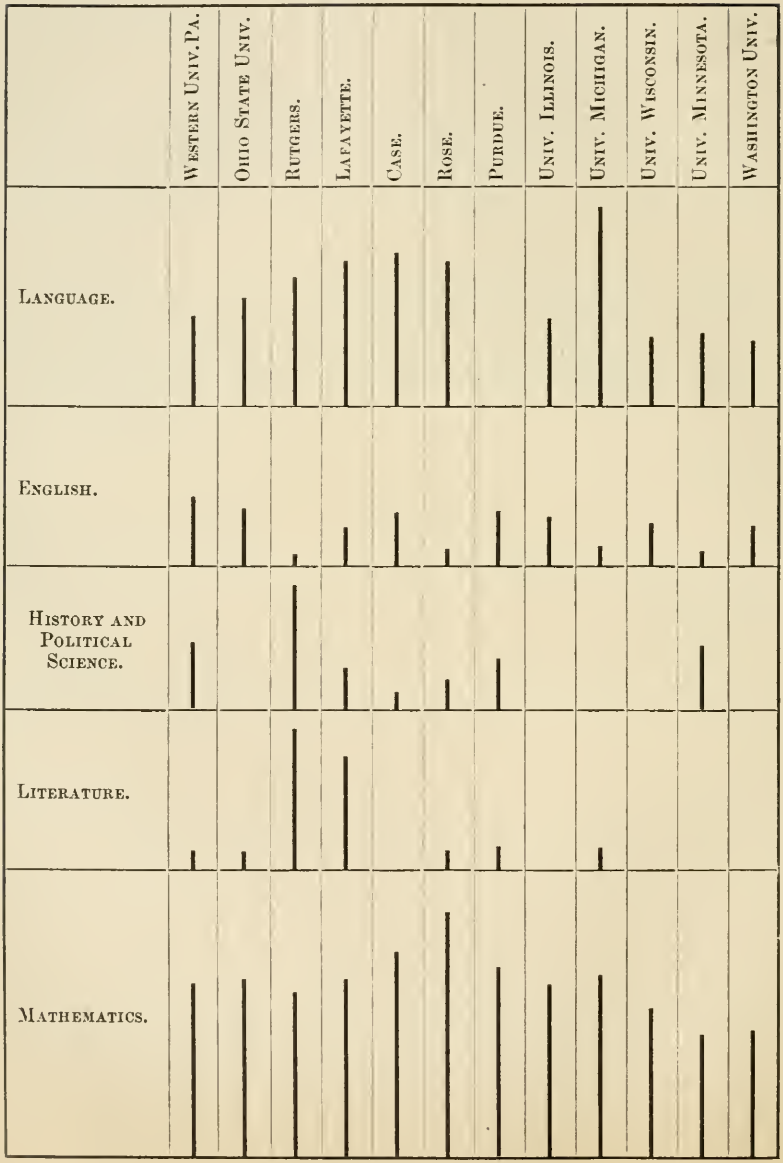
What shall be said of the later practice of the man who has not had the liberal training? With the present large number of engineering colleges, competition among their graduates must be very brisk; and, omitting exceptional cases, the man whose education has been broad enough to develop the man, as well as the engineer, will certainly outrank the one who is the product of the limited training of a purely technical course. The lower places in the engineering field must fall to the latter class. It is a fundamental principle that in order to rear a spacious structure a broad foundation must be laid.

Training which leads in but one direction is not the best education. The young man who is ambitious to compete creditably with his fellows must possess the refinement, accomplishments and general culture of a gentleman in the best sense of the word; the habits of close observation and power to form correct conclusions of the good business man, in addition to a solid foundation of theoretical and practical technical knowledge. A man of moderate ability, with this training, will almost certainly outrank a man of exceptional ability whose whole training has been narrowly specialized.

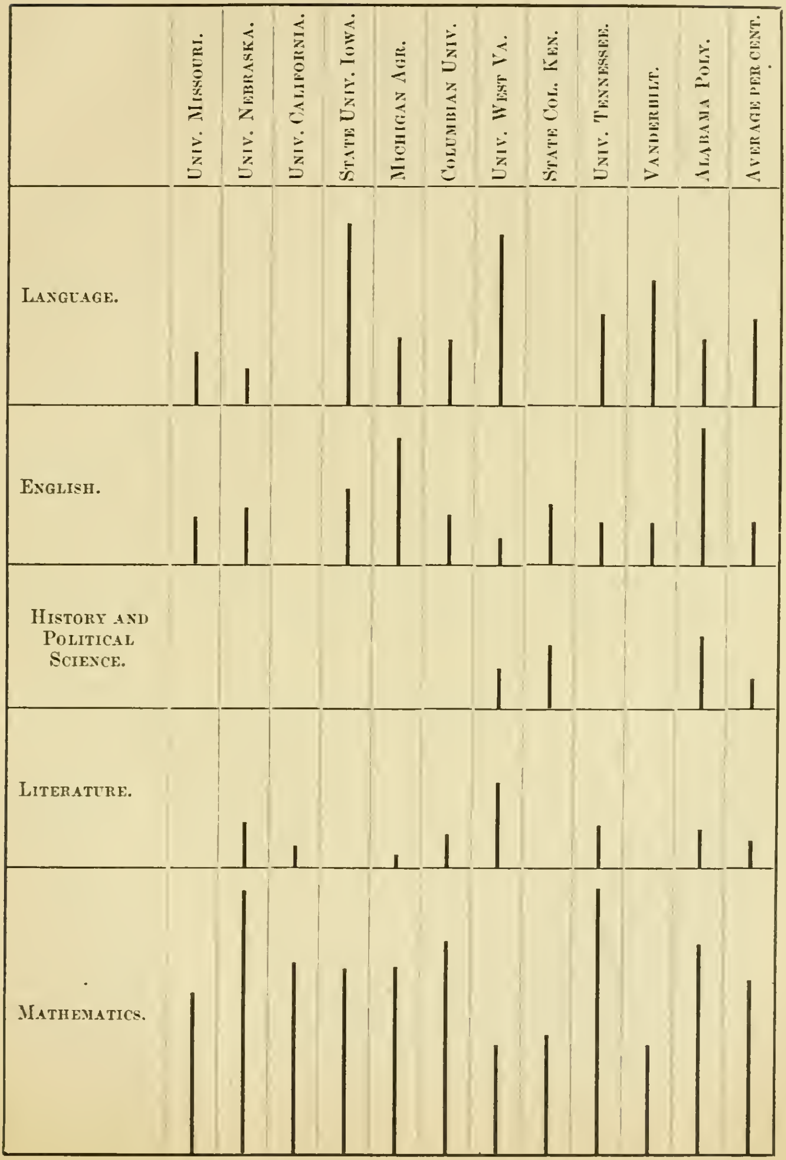
The following charts show graphically the relative amounts of time given to different subjects in thirty-five institutions. The heavy lines represent percentages of total work on a scale of one-sixteenth inch to one per cent.



Scale $\frac{1}{16}$ inch = 1 per cent.



Scale $\frac{1}{16}$ inch = 1 per cent.



Scale $\frac{1}{16}$ inch = 1 per cent.

THE ELECTIVE SYSTEM AS ADOPTED IN THE MICHIGAN MINING SCHOOL.

BY M. EDWARD WADSWORTH,

Director of the Michigan Mining School, Houghton.

In the United States two systems have been chiefly followed in the higher educational institutions—the Fixed and the Elective. The latter was introduced first in this country by President Wayland, of Brown University, and it has since been systematized and developed with remarkable skill and success by President Eliot, of Harvard. Indeed, the system has proved to be so well adapted to the needs of modern times, and to be so popular, that it has made its way in the face of strenuous opposition, until all or nearly all of our colleges and universities have employed it for their work in general or literary, and scientific education.

In technical or engineering education the case has been different, since even those colleges, like Harvard, Leland Stanford, or the University of Michigan, which have a most liberal elective system for general education, have still only a partially modified form of the rigid system in the engineering or technical courses. The rigid system is disguised in most institutions in their technical work under the head of election between various fixed courses, which may or may not have a few options, or it masquerades under an elective dress to which it has but little, if any, right.

The elective system proper in any of the higher institutions giving general education, consisted of two features: 1st. The Essential Studies. 2d. The Sequence of Studies. The first is composed of those studies which are considered in each institution as necessary, or essential to maintain the scholarship or traditions of the school in question, and in engineering courses, not even excepting that at Harvard, the required or essential studies to-day constitute the chief amount of the entire course in any of the engineering branches. In the case of general or literary education, the number of studies that are considered essential usually rapidly diminishes, according to the experience and number of the faculty, until only a few studies are required; and in time this feature will be fully eliminated.

Regarding the second, or "The Sequence of Studies," but little public attention is called to it in any statements relating to electives in any institution, although it is the keynote of them all. No school can maintain any elective system, or any work above a kindergarten or primary grade, without carefully considering the question of the natural sequences. It is the unwritten law that no student can take calculus who has not previously prepared himself in algebra, nor can he study petrography without any knowledge of mineralogy.

All the catalogues of the advanced institutions show that they tacitly recognize the law of sequence of studies with greater or less fullness, but I do not know of any which call attention to the fact, except the recent prospectus of the Michigan Mining School.

In truth, the greatest curses that beset any system of electives are the neglect of proper sequences in the studies, and the tendency of various instructors to bid for students by giving weak and inferior (technically known as *soft*) courses. This last, like many of the other ills of educational institutions, can be partially, if not entirely, removed by placing the charge of the instruction under one experienced executive head, which head is to be held strictly accountable for the success of the work, and is to be given absolute control over all the instructors, with power to discharge them if they do not properly perform their functions. In other words, there should be introduced into our colleges more of the business methods of successful business houses—the direct responsibility for and power of the individual over everything placed under his charge.

The Michigan Mining School has attempted, so far as the institution's province of training men to assist in the development of the mineral wealth of the country will enable it to do so, to apply to technical or engineering education, the methods in use in the elective systems employed for general or literary instruction. In accomplishing this it has tried to reduce to a minimum all studies to be taken by every student, to conserve the sequence, and to obtain thorough work by the business method of individual responsibility.

The only studies required of all the pupils here are Elementary Geology and the Elementary Principles of Mining; these are asked for, because it is believed that in any institution dealing with the problems relating to the mineral wealth the pupil should have some knowledge of geology and of mining methods, and also because the Director (who in this case happens to be in charge of the geological instruction) desires to come into personal contact with every pupil in the school, early in his course. The above-mentioned studies require, altogether, the pupil's presence in the classroom, only three times a week for thirty-four weeks.

Outside of the Elementary Geology and Mining the student is allowed unrestricted freedom of choice in his studies, the same as he is in the literary, but not in the engineering, courses of Harvard, Michigan, or in any other of our Universities.

Emphasis is here placed upon the almost absolute freedom of choice at the Mining School, because many have mistaken the natural "sequence of studies" for "required studies." This error happens because in the prospectus of the elective system, issued last May, special attention was called to the natural sequences in chemistry, metallurgy, mechanical, electrical and mining engineering, ore-dressing and geology, provided any student wished to obtain every particle of instruction that is given in the Mining School in any of the subjects named. These outline schemes are merely signs showing the student some of the numerous ways of reaching the upper rooms of the house, but he has absolute freedom to use any of the other numerous ways that might just as well have been pointed out. Owing to the fact that in the usual discussions of elective systems the natural sequence of studies is not dwelt upon, it was expected that these guiding lines would be mistaken for required courses by many readers, although it was thought the error was sufficiently guarded against in the prospectus on pages 11, 13, 14 and 25. The precaution seems not to have been entirely successful, since a friendly hand in a friendly journal* has penned the following: "Students are allowed to select one of several courses with a certain principal subject, and in each course certain studies are required and the rest are elective. The school thus allows greater freedom in the selection of studies than do most mining schools." This friend has entirely misapprehended the facts, as the statements made above show. The freedom of choice is not only greater than that allowed in all other mining schools or colleges, but, so far as the present writer is aware, also greater than that in all other technical or engineering colleges whatsoever.

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* American Geologist, 1895, XVI., 130.

Although this is the first time this general freedom has ever been granted in any engineering college, the problem seemed to be so fully solved, so far as the special conditions of this institution are concerned, that when it was brought before the Faculty and the Board of Control it passed both bodies without a single objection. The ostensible working of the system does not go into full effect until September 16th of this year, yet the choice of electives has already been made, and the passage of all the students from a rigid system to an elective one has been accomplished without any hitch or difficulty, and also with the students' unanimous approval.

The courses in operation up to the time of commencement, August 16th of this year, were two exceedingly rigid ones. The required work demanded of the student from seven to ten hours a day, five days a week, for forty-five weeks a year, and for three or four years (according to which course was taken) in the class room, laboratory, field, mine, or mill, while his daily preparatory work had to be attended to in outside time. When it is considered that all students, both special and regular, have been transferred, not only without trouble, but with general satisfaction, from one system to the other, the success seems almost phenomenal.

In the elective system of the Michigan Mining School the unit of work is taken as three hours a week in the class room, or nine hours a week in the laboratory, for thirty-four weeks; and this amount of work is called a course or a full course, while any subject scheduled in the prospectus for less time is taken for its proportionate part of a full course. The student, to obtain the degree of Bachelor of Science, must complete eighteen full courses, and to obtain that of Mining Engineer, twenty-two full courses, which in both cases include the subjects of Elementary Geology and Mining.

Owing to the fact that the regular work in the Michigan State Mining School extends through forty-five weeks of the year, a good student can obtain his degree in three or four years, depending upon the question of whether he remains during the entire forty-five weeks each year, or for only the first thirty-four weeks, or also whether he wishes his course to be largely of practical or of theoretical work.

At the present time this institution has announced sixty-five different subjects or studies from which the pupil can make up his eighteen or twenty-two courses, only one of these full courses being of required work. In a required system of study the pupil can be carried over all the subjects that experience considers necessary for the successful prosecution of his future profession, but this is always done at the expense of thoroughness, and it pays but little or no attention to the individuality of every student or to the rapidly increasing specialization of work in every subject. It gains breadth, but it is at the expense of depth.

In an elective system the individuality of the student, the specialization of work in modern times, and the limitations of human capacity, are all considered. It loses in breadth, but it gains in the greater interest and, consequently, greater depth of the work done.

Much can be said in favor of both systems, as the writer knows from long experience with both; but there is one point that ought to be the controlling factor in every engineering college in deciding what it will do for the future. If the signs of the times and the history of education are read aright, this is true and certain, that whether we like the elective principle or not, whether we are willing to adopt it or not, every engineering or technical college in the land must and will adopt it in its entirety sooner or later, or else perish. It needs no Daniel to read the handwriting all over our walls.

Discussion.

Prof. Mansfield Merriman said that in regard to courses in mining it seemed to him that there was a greater freedom in choice and arrangement of the subjects than in any other kind of engineering courses; that it was also very true that the number of students had decreased in a marked degree within a few years. Some mining courses, in fact, had gone out of existence altogether, owing to lack of students. He thought that the freedom of election had been one of the causes of the students leaving the mining course of study and going into chemistry and civil engineering. The systematized courses appeared to be far the best, and if options were allowed, it seemed preferable that they should be confined to the senior year.

Professor J. Galbraith felt that a system of the kind proposed in the paper was surrounded with great difficulties. If the student were to be left perfectly free in the choice of the courses of study these courses would require to be perfectly self-contained, and there might be a great amount of overlapping in those selected by a student for his diploma. This overlapping means waste of time and labor. If the courses are arranged so that the number of combinations is very limited the students will be obliged to consult their teachers as to the best sets of combinations. Thus the so-called elective system will resolve itself into something very like the authoritative system. Students, as a rule, are not qualified to select the various courses necessary for an engineering diploma. The experiment will be watched with interest. It appears to the speaker that a great deal of the desire at present noticeable among students for freedom of choice in their studies arises from their false conception of the German student. The latter is given in the university great freedom. Our students see this, but they forget or do not know that the German student has already gone through a discipline of the most severe kind, stretching over eight or nine years in the gymnasium or the Real schule, which has little or no counterpart in this country.

Professor John M. Ordway would distinguish in this matter between the option of subjects and the option of courses. The students should be required to take up certain subjects, such as hydraulics. Mining engineering might be divided into two or three different sections. One would involve more chemistry, another more of civil engineering and another more of mechanical engineering. The student should be allowed to choose one of those courses and the subjects that belong to it, and not to select individual subjects.

PROFESSOR HEINRICH O. HOFMAN explained that at the Massachusetts Institute of Technology a few years ago there were in the mining department four different options with special reference to mechanical, civil and chemical studies, in order to satisfy the demands, in addition to the general mining and metallurgical course which a student took, if he showed no special preerfence for any of these branches. After a few years these options were found to work unsatisfactorily and this for two reasons: First, they required a larger number of special teachers than it could very well be demanded of any school to furnish; and secondly, students who had chosen one of the three special options found that the situations open to them after graduation were probably not in the special line they had selected. The department had now dropped two of the options, retaining the one in which the main study was mechanical engineering. It advised every student who did not know definitely that he was to enter the iron and steel industry to take the general course as the only satisfactory way of thoroughly equipping himself to take up any branch of practical work.

GRAPHIC METHODS IN ENGINEERING EDUCATION.

BY L. M. HOSKINS,

Professor of Applied Mechanics, Leland Stanford, Junior, University,
Palo Alto, California.

The claims of graphic methods to a place in our courses of study have been repeatedly urged, and in most American technical colleges have received a certain amount of recognition. In the majority of our colleges, however, these methods occupy only a subordinate position. Graphic statics usually finds some place in the curriculum, but the attention given to it varies from a few lectures up to a systematic course of several months. Few, if any, of our American colleges offer so extended a course as is often given in Europe. General graphic methods commonly receive little or no systematic treatment, although probably the majority of teachers make more or less use of them incidentally. It is thus sufficiently evident that graphic methods are held in quite various degrees of estimation by those who shape our courses of instruction.

This variety of opinion is doubtless due in some measure to differences of individual training. The method a person has most thoroughly mastered is very likely to seem to him the best, so that it is not easy for him to give the question wholly unprejudiced consideration. It is quite possible that, while on the one hand too much has been claimed in behalf of graphic methods, there has been on the other, a failure to recognize their full value.

In attempting to consider impartially the proper relative position of algebra and graphics in our courses of study, it will be useful to keep in mind certain general principles. Methods of instruction should be chosen with a twofold object; the student should gain a clear knowledge of general principles, and he should also acquire facility in the application of these principles to particular problems. Of these objects, the first should be fundamental, the second subsidiary to it. The usefulness of a general principle (at least so far as the practical requirements of the engineer are concerned) consists in its applicability to the solution of particular problems; moreover, one can rarely be sure of his grasp of a general principle until he has tested his ability to apply it to a particular case. But it is none the less true that the general principle is more important than the special problem. Engineering is scientific just in proportion to the generality of its principles and methods.

A comparison of algebraic and graphic methods indicates that each possesses certain advantages. On the side of algebra the main advantages are generality and precision. It cannot be denied that graphic methods fall far short of algebraic in generality. Algebraic analysis is applicable to the development of almost any subject, and to the solution of all manner of problems. The methods of graphics, on the other hand, are to a large extent special, applicable only to particular problems; so that for every new problem a new method of treatment must be devised. Again, the degree of precision attainable by graphic constructions is limited, while the methods of algebra and arithmetic are subject to no such limitation. In some cases this is an important consideration, in many cases not. Thus, while many of the trigonometrical problems of surveying are readily solved by graphic construction, such solutions are usually not sufficiently precise. On the other hand, the degree of precision requisite in most problems of applied mechanics is readily attainable by graphic methods.

The chief advantage of graphic methods is the saving of labor which often results from their use. The methods of algebra and arithmetic, in spite of their generality, have practical limitations. The algebraic treatment of a problem often leads to complicated expressions which can be handled only with great labor. In such cases the labor may often be greatly abridged by use of graphic constructions. The writer recalls an instance in which it was desired to compute a series of values of a complex expression, involving trigonometric and logarithmic functions. The computation by use of tables seemed to involve many hours of labor; but a careful inspection suggested a graphic construction by which the required computations were made with all requisite precision in a couple of hours. One who is accustomed to look for graphic methods is sure to meet many such instances. Another consideration of no slight importance is the gain of clearness that often results from the use of graphic methods. Many minds find great difficulty in grasping clearly the meaning of algebraic formulas, while the same relations exhibited graphically are readily understood.

Much more might be said in detail regarding the relative claims of algebra and graphics, but these seem to be the most important of the considerations that should govern us in assigning to each its proper position.

Bearing in mind the principles already stated, it is not difficult to reach a general conclusion regarding the question before us. If it is true that a method is important in proportion to its generality, algebraic methods should unquestionably be made fundamental. But on the other hand, the undoubted value of graphic methods in saving labor and in promoting clearness of thought would seem to entitle these methods also to a position of some importance. If it were necessary to sacrifice one or the other, undoubtedly graphics could be spared better than algebra. But it is not necessary to sacrifice either. It is true that the limitation of time is often an important consideration. There has been in recent years an increasing tendency to specialize our courses with the object of giving direct preparation for practical work. Up to a certain point this undoubtedly increases their efficiency; but the resulting tendency to shorten the time allotted to to the general subjects of the course must not be permitted to go too far. The general subjects are after all of paramount importance. The general principles of geometry and mechanics are fundamental to all branches of engineering; and these, together with those mathematical methods which are necessary for their efficient development, must remain the basal subjects of the course, in whatever direction it may later be specialized. Too high a degree of efficiency can not be attained in these fundamental subjects; and a proper use of graphic methods can not fail to be of great service in promoting this efficiency.

It remains to consider the specific question how much time may properly be given to graphics in the ordinary four-years' course, and the related question whether graphic methods should be taught in independent courses, or in connection with algebraic methods.

At the first meeting of this society a paper was read in which was strongly urged the desirability of introducing an independent course devoted to the general subject of graphics. The merits of this proposition can not well be judged without specific information as to what the proposed course is to include. If the graphic methods of use to the engineer can be shown to admit of independent development and systematic presentation, the claim for an independent course devoted to them may perhaps be admitted. But the fact seems to be that, of the graphics of which the engineer can profitably make use, a large part is not systematized, but consists of unrelated methods applicable to special problems. So far as this is the case, these methods may be best explained in connection with the general treatment of the particular subjects concerned. The case in favor of an independent course in general graphic methods does not seem to be established.

With graphic statics the case is different. The science of statics has been shown to be peculiarly adapted to graphic treatment. In fact, that part of statics which is of particular importance to the engineer admits very largely of independent development by graphic methods. In view of this fact, there is an advantage in devoting an independent course to the subject. This course may run parallel with a course in which algebraic methods are used, or one may follow the other. The latter method has the advantage that one course serves well as a review of the other. In any case the student should be led to compare the two methods, and to appreciate their relative advantages and disadvantages.

As to the extent of the course in graphic statics, two opposite errors must be guarded against. On the one hand, when the subject is treated in an independent course, there is danger of too great elaboration. Graphic methods in statics have been developed far beyond the point at which they are of practical use to the engineer. The instructor is liable to be led on by the fascination of the subject to a forgetfulness of the importance of other branches and of the limitations of time. This danger exists in all subjects, but is especially great in the subject under discussion. On the other hand, there is danger of making the course unduly brief. Although the fundamental principles of the subject are not difficult, the average student does not master them without careful study and practice. The opinion seems to prevail in some quarters that the only preparation in graphic statics which is of real value to the student is the ability to draw in a mechanical manner simple stress diagrams. The views of practicing engineers who are equipped with a knowledge of graphic methods are a sufficient refutation of this opinion. A graphic construction should not be a mere mechanical process. Sufficient time should be used in class and draughting room to give the student an independent grasp of the main general principles.

For an elementary course in graphic statics, covering only those portions of the subject which may profitably be taken by all engineering students, the writer's experience indicates that less than a third of a year is inadequate to the attainment of the desired object. Students specializing in bridge or structural engineering may profitably take an advanced course of a semester or more, according to the time available.

As to the time to be given to graphic methods aside from statics, it seems impossible to lay down any definite rule. If, as above suggested, these methods are to be introduced into particular courses wherever found useful, rather than treated in an independent course, the time devoted to them must be fixed by the requirements of each particular case. The writer believes strongly that the student should be led to acquire the habit of looking for graphic methods, as well as some facility in using them; and that a considerable amount of time devoted to these ends will be well spent. In this connection it may be suggested that an important part of the student's equipment is a thorough familiarity with elementary geometry. The importance of this is too often overlooked. Geometry is one of the standard requirements as a preparatory subject, but in the university or technical college, geometry often yields almost wholly to algebra. The conic sections are usually studied, but only in the course in analytical geometry; and often the impression is left with the student that the geometrical relations are of less importance than the algebraic processes. It is not surprising that students are often slow to appreciate the value of graphic methods.

A word of a general nature may be added in conclusion. In the foregoing discussion it has been tacitly assumed that each subject in the course should be pursued only so far as it admits of practical application in the work of the engineer. Limitations of time make it necessary to apply this rule to the majority of subjects. No one, however, believes more firmly than the writer that the education of the engineer should not be limited by any narrow standard of utility. If time permits, many of the subjects of the course may profitably be pursued far beyond the special requirements of the engineer. It is most desirable also that time should be available for such general subjects as literature, economics and history. The ideal education for the engineer must be both broad and practical. To approach this ideal without unduly lengthening the time devoted to the course is the difficult problem which engineering educators are called upon to solve.

Discussion.

Professor John B. Johnson hoped to hear a few words from Professor Woodward on this subject; he had heard him give expression to some interesting ideas on it, in Chicago.

Professor R. S. Woodward was sorry not to have been able to attend the meetings continuously. What he heard of this paper coincided very nearly with his own views. He heard at Chicago a discussion of this question. The ground taken by him was not at that time very much occupied, and so he took what he thought was the "other side," quite as much because of that fact as anything else. Nearly all present were familiar with the fact that there was a considerable number of engineers now who were deeply imbued with the graphic process, that they applied it to everything, almost. This was sometimes unprofitable. The reason why that process was resorted to so frequently was that almost all our students, as they came up from the preparatory schools, had an excessively bad preparation in arithmetic. In his own experience, in teaching, the greatest difficulty to the students who studied analytical mechanics was in the use of arithmetic, and he was compelled to teach arithmetic continuously. It was rare to find a man who could go through a long calculation and know when he reached a correct result. For work in three or four figures one should use tables, rather than try to do with elaborate pictures what could be much more easily done with ordinary appliances.

Professor Johnson said, as related to this paper, and perhaps better stated here than anywhere else, that he believed in insisting upon the teaching of the use of the slide rule. When the subject of logarithmic tables was reached, then the theory of the slide rule should be taught immediately and its use encouraged throughout all the rest of the college course. It was an instrument that was in common use in all of the bridge offices, and the Thatcher slide rule carried very readily the results to four places if the first figure was more than five, and to five significant figures if the first figure was less than five; thus making it an accurate instrument of computation in ninety-nine cases out of a hundred in which the engineer had to work. Either that or the common pocket slide rule should be used. The latter rule was almost universally used abroad, but was seldom seen in this country. It should be taught scientifically, and that was one of the applications of graphics. Keuffel and Esser, New York, have placed a very good student's slide rule on the market at the low price of one dollar.

PROFESSOR MANSFIELD MERRIMAN called attention to Professor Hoskins' statement that the algebraic methods were more general than the graphic. It seemed to him that the reverse was true. The geometric, or graphic, method was general; the result was special. The algebraic method, as applied to a problem, as a rule was a special treatment, but the result, when reached, was a general one. Algebra is easier than geometry because it is special and not general. Geometry is a more powerful instrument of investigation than algebra to those who can use it. If there is any branch of elementary mathematics that needs improvement it is geometry. There are few boys from fourteen to sixteen years of age who can go through a course of geometry and master it thoroughly, unless they have a bent in that direction. They may demonstrate the propositions and meet the requirements of the teacher, but their ability to use the geometric method is usually not of a high order.

PROFESSOR FRANCIS R. FAVA believed that the success in teaching graphical methods, or the non-success so far had been due to the fact of some lack of system. All courses should coöperate, and each instructor should measure how far graphical methods are applicable in his line.

SPECIFICATIONS FOR TEXT-BOOKS.

BY IRA O. BAKER,

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The author recognizes that there is a just criticism against one method of using text-books, but he believes that there is a proper use of them and also that they should be of the very best. The latter is a particularly important matter for engineering colleges, since almost without exception they take young men from eighteen to twenty years of age who have little or no experience or knowledge of things engineering, and attempt to give these young men a general education and also a professional training in four years. The task is Herculean, and a modicum of success can be attained only by removing every obstacle and employing the most efficient methods. The writer has long believed that there was opportunity for a very considerable improvement in ordinary text-books, particularly the technical ones used in engineering colleges.

The object of the present paper is to suggest some of these improvements, with a hope that some benefit may be derived from these suggestions and that the labors of engineering professors may be lightened and the engineering students be profited. The author hopes that no one here present will fail to enter an objection, if he dissents from any of the statements made by the writer; and he also hopes that those who hear this paper will present in the discussion further suggestions as to conditions to be observed in the preparation of text-books.

The writer believes that some of the specifications intended primarily for text-books are applicable also to engineers' official reports, to contributions to engineering society proceedings, and to articles in engineering periodicals. Current technical literature constitutes a not inconsiderable part of the material employed by the engineering instructor in educating his students, and for this reason alone the professor is very much interested in the general form in which such literature is presented to the public.

1. The first requisite of a text-book is that the language shall be clear and concise. Not only should the statements of the text be clear when standing alone, but the writer should have in mind the degree of preparation of the student and fit the statement of the text to the probable mental content of the reader.

Writers of technical books appear to be more concerned in showing the depth of their own learning, than with the method of imparting knowledge. Ruskin has said that one of the greatest feats of the human intellect is to see something clearly, and then to describe it in plain and simple language. Writers of text-books doubtless feel that they have seen something worth describing, but their vision is largely useless unless they reveal it to others. How many times in your own reading, are you compelled to re-read a part of a sentence or a whole sentence or even a paragraph, before catching the meaning of the printed page? The learner who is investigating the matter for the first time will inevitably lose his interest and secure at best a clouded view, if he is compelled frequently to retrace his steps and read again that which should have been clear at the first reading.

2. The subject should be presented in accordance with fundamental pedagogical principles.

Perhaps I can make my meaning most clear by an example covering one phase of the subject. In a mathematical text-book much used in colleges a few years ago, the method of treatment was to begin each new proposition by calling attention to certain geometrical relations in a figure of the text, and then directing the student to perform certain algebraic operations, and finally drawing the conclusion. The student was left to grope his way through the several operations without the least idea of the purpose or object of the investigation, until he arrived at the end of the discussion. In this particular, Church's Descriptive Geometry is an ideal of the proper method.

This is a very important matter, second only to the preceding; but it is difficult to discuss it in general, and hence enough has probably been said.

3. A text-book should be more than a cyclopædic collection of facts. The facts of the book should be grouped to develop and illustrate fundamental principles. Many text-books are too comprehensive and contain more matter than can be assimilated by the student. The ideal text-book should give a clear and complete discussion—a little more than the student can master in the time available, but not loaded with details. Supplementary and explanatory matter should be printed in smaller type.

4. The matter should be classified by being properly divided into chapters, articles, sections and paragraphs. Text-books are usually divided into chapters, but the chapters are not always arranged in a logical order. In

a book before the author as he writes, fully half the chapters seem to be located by chance. Such an arrangement not only makes it difficult to find what is said upon any particular subject, but must inevitably prevent the student from getting as clear and comprehensive a view of the subject as he otherwise would.

Some authors of text-books seem to believe that chapters should contain only about a certain number of pages. This method of division has certain advantages for a novel published as a serial, but is unworthy a scientific treatise. Again some authors apparently desire paragraphs of nearly uniform length, irrespective of the sense. The writer knows a book in which the students nearly invariably make a mistake in referring to an important paragraph, as they must frequently do, because the author chose to put a limiting condition in the last sentence of an unrelated preceding paragraph.

The division into chapters, articles, sections, and paragraphs should be wholly for the purposes of classification. To do otherwise is loose and unscientific, and tends to develop in the student slovenly habits of thinking and working.

5. The several divisions and subdivisions of the chapters should be clearly indicated by distinctive headings. An excellent way of indicating these several divisions is to divide the chapter into articles, each having a serial number; to designate the major divisions of the articles by capitals or small capital sub-heads of a style of type different from that of the body of the page; and to indicate subdivisions of articles by small capitals or italic side-heads. Still

further subdivisions may be designated by section marks with or without serial numbers, or the serial number may be used for this purpose without the section mark; but in either case, the section mark or the number should be of a style of type different from that used in the body of the page. Indicating the section by the serial number, permits a convenient and valuable system of cross references.

If the headings are designated by some such system, the reader can get a comprehensive view of the subject simply by reading the headings, which is of very great advantage to the student in studying his lesson for the first time, and in reviewing, and also in using the text-book as a reference book.

Not only should the several divisions have distinctive headings, but the position or style of type, or both, should indicate the relation of the several subdivisions. Without a proper subordination of headings, it is sometimes difficult to understand the text. The writer is familiar with a book, in several particulars a most excellent one, which had been used for a number of years with unsatisfactory results. The teacher finally concluded that the difficulty was that the students did not have a clear conception of the relation of the several parts, owing to a faulty arrangement of the headings. Sometimes the heading of a minor subdivision was printed in the position or style of type of a major division; and *vice versa*, some of the major divisions had the same form of heading as the minor subdivision. Naturally the student had never discovered the logical relationship. After preparing an analytical table of contents of the most difficult chapters, marking the headings in the book accordingly, and transposing a few subjects, the difficulties vanished. Possibly this may seem a trivial matter, but after several years of observation, the writer is convinced that it is well worth consideration in writing or in selecting a text-book. As instructors, the members of this society should carefully consider such questions, if we are to economize the students' time and make the most of our own opportunities.

6. The typographic arrangement of the book should be such that the reader can easily find any particular portion. The running title at the head of the page should indicate the different divisions of the book. An excellent arrangement is that in which the left-hand page shows the title of the chapter and also its number, while the right-hand page shows the number and subject of the subdivision of the chapter. Careful attention to these matters will save the reader much time in turning to the different parts of the book. This saving is particularly important in consulting reference books, and many text-books are used also as reference books.

At present, the heading at the top of each page usually consists of the title of the book, an arrangement which makes the convenience of the manufacturer of the book subservient to that of the user.

7. As far as possible all figures and diagrams should be inserted in the text, and a little study in locating these diagrams will save considerable annoyance to the reader. For example, not infrequently the diagram is placed on the right-hand page, and the text which requires frequent reference to the diagram,

is placed upon the succeeding left-hand page; consequently the reader must each time turn the page over to consult the diagram. In the example assumed, the objection could be removed by placing the diagram on the succeeding, instead of the preceding, right-hand page. Of course the remedy is not always as simple as in the illustration above, but a very little attention to this matter would greatly improve many text-books.

If possible, each figure or diagram should contain upon its face some hint or suggestion as to the matter represented. For the sake of easy reference, this legend should not be placed in the body of the diagram; and for the sake of uniformity, it should be at the bottom rather than at the top of the figure.

8. Folding plates should be placed at the end of the volume. If they are distributed through the book, they interfere with the rapid consultation of the text; and if they are referred to by number, it is very difficult to find them.

The folding sheet should have a blank stub at the inner end, such that none of the printed matter can be covered by the adjoining pages of the book. With this arrangement, when the plate is spread out both it and the explanatory text may be consulted without the interference of the intervening portions of the text.

Each folding plate should have upon its face the number of the plate, a descriptive legend, and a reference to the portion of the volume where the explanatory text may be found. This title should be placed also upon the outside fold, as otherwise much time is wasted and the plates are injured by unfolding several in search of a particular one.

9. The clearness of matter containing mathematical formulas can be greatly increased by even a little attention to the nomenclature employed. In the first place, the characters used should suggest the quantity represented. For example, R is a much better designation for the radius than a or k; and R and r are much better designations for large radius and small radius, respectively, than R' and R''; also R_i and R_o are better designations for the radii of the inside and the outside rails, respectively, than P and Q, or r and R, or R' and R'', or any other combination that can be devised. Again H' and H_1 are much better characters to represent the barometric reading at the upper and lower stations, respectively, than H and h, as are frequently used. Doubtless some of my hearers have been compelled to insert a rational nomenclature before being able to decipher some otherwise comparatively simple matter. Other things being equal, the nomenclature employed should be that used by other writers on the same subject.

It is very desirable that as nearly as possible, the same nomenclature should be used throughout the volume, and that the same character should not be employed for two purposes in different parts of the book.

The nomenclature should be explained before it is used. Frequently a reader is compelled to skip the formula and read the nomenclature, and then turn back to the formula.

Finally, the nomenclature should be stated in a form convenient for ready reference; and rarely, if ever, should the explanation of the nomenclature occupy an obscure parenthetical phrase of the text.

10. There is room for great improvement in many text-books in the manner of printing formulas. For example, it is much easier to understand the following expression in its first form than in its second:

$$\frac{b}{a} \sin \theta ; \qquad \frac{\sin \theta\, b}{a}$$

It is undersirable to use two systems of nomenclature in the same formula. For example, it is unfortunate to designate one line by a single letter, and another line by two letters, one for each end. If this condition can not be satisfied, the objection can be lessened by attention to the relative space between the several letters.

For convenience of reference, particularly in the recitation room, each formula should have a serial number. This series should be continuous through a chapter or, at least, a major division thereof.

11. Each table should be designated by a serial number, for convenience of reference. Even though the author himself does not refer to the table by its number, the instructor in the recitation room frequently has occasion to make such reference.

All tables should carry at their head, an explanation of their contents. Astonishing as it may be, it is not unusual to be compelled to search the text line by line for the meaning of some table. It is needless to say that such a table is of little or no value, unless the reader supplies the necessary explanation by his own hand upon the face of the page. Each column of the table should contain a statement of its contents or an explicit reference to such a statement.

The relative order of the columns is also a matter worthy of consideration. Not infrequently two columns which must be used together, are placed on opposite sides of the table.

For convenience of reference, particularly in the class room, it is desirable that each horizontal line of the table should be designated by a serial number.

For convenience of consultation, the table should be divided horizontally by what may be called blank lines. If there be no divisions depending upon the nature of the table, these horizontal subdivisions should be placed every three or five lines. The first is the better, but is the more expensive. Almost invariably logarithmic and trigonometric tables are divided horizontally into sections of ten lines each, which arrangement requires both hands, or a straight edge, to take out numbers. If such tables were divided horizontally into sections of five lines each, numbers could be taken out without following a line across the page with a pencil, and hence the table could be used more rapidly and with less fatigue to the eye. Of course, a division into sections having less than five lines each would be still better, but is more expensive.

For convenience in using, the major vertical divisions of the table should be indicated by a double rule.

Sometimes an author, instead of presenting his tabular matter in two or three long narrow columns, cuts it up into sections, and prints them side by side instead of end to end. This arrangement brings sections of the argument in parallel columns, which is unfortunate, since there is danger that the argument in the first section of the table may be used with the results in some of the succeeding sections. For example, Carnegie's Pocket Companion, edition 1892, page 107, contains a table of this sort, with which the writer's students have frequently made errors by using results in the second portion of the table with the argument in the first part. The defect in the arrangement of the table is in not distinguishing clearly the two parts of it. In other words, there should have been a heavy vertical line through the middle of the table to separate the two portions. As a general rule, it is much better to present a single narrow table than a double or divided one.

Every table should contain in the text some reference to it. The writer has frequent occasion to consult a book which contains a number of convenient and valuable tables of which a careful reader would be entirely ignorant, except as he should accidentally discover them in turning over the collection of tables at the end of the volume, and but few students do so discover them. The writer has been trying for over a year to find the meaning of an apparently valuable table in a United States public document published by one of our most noted scientific bureaus.

The collection of "useful tables" frequently printed at the close of the volume should be preceded by a list of titles.

12. All cross references should be to the page rather than to the section or article. The author is aware that this requires page or plate corrections, but never-

theless he firmly believes that the advantage is well worth the cost. It is difficult enough to persuade students to look up cross references, and it is certain that very few references by section or article are ever consulted.

It is insufficient to refer to a formula simply by number. While preparing this paper, the writer had occasion, in connection with another matter, to consult a nearly ideal text-book; but the two or three lines which he wished to examine contained a reference to an equation designated simply by number, and the writer was compelled to turn about twenty pages before he could find it.

13. All excerpts should be published with the original pagination; and all references to such matter should, if possible, use the original pagination.

14. Each volume should have a full analytical index with page references. There is no probability of making the index too full. The references should be to the page, instead of the section or article.

Incidentally it should be noted that a table of contents, however full, is not an equivalent of an analytical alphabetical index, the practice of some authors to the contrary notwithstanding.

15. The mechanical execution of the volume should be in keeping with its literary qualities. But as this paper is already of unexpected length, the writer will not discuss this phase of his subject, but invites suggestions on this point in the discussion of the paper.

Discussion.

Prof. Frank O. Marvin thought large volumes objectionable for many purposes. In many cases if books were cut in two in the middle it would be desirable, for in that event, the first part would often be used where the book, as a whole, might not be generally used, and at the same time furnish volumes of portable size instead of one bulky book for those using the entire work.

Prof. Henry S. Jacoby desired to call attention to one point, and that was in regard to the notation employed in formulas. It was a matter of great importance, because of the fact that students had to remember a large number of these letters and the things which they represented. In algebraic processes certain letters were employed whose use was so general that they ought to be made universal; for instance, I for moment of inertia; v for velocity; l for length; M for bending moment, etc. Some systems of notation required an undue amount of effort to remember what was represented. There often seemed to be no relation whatever between the letter used and the word for which it stood. If, therefore, a natural system could be found, it would be desirable to follow it just so far as possible.

Prof. Francis R. Fava, Jr., felt this to be a very important subject—that of notation—and asked if this Society could not appoint a committee to study this matter and report at some other session. This suggestion was made, however, without any desire to be a member of such committee.

THE PRESIDENT suggested that this question be postponed until Wednesday, when, at the business meeting, the suggestion could be put in the form of a motion, and acted upon.

PROF. MANSFIELD MERRIMAN alluded to the old saying which stated that the appendix is the soul of the book, where the author is not constrained by the formality of the text. Of late years however, some authors have been putting into the appendix a mass of matter clipped out of engineering periodicals, which certainly might be better referred to by a descriptive index.

PROF. C. FRANK ALLEN referred to a point which he did not remember as being advanced in Professor Baker's paper. In demonstrations in text books, it was very desirable to avoid doing either too much or too little for the student. A golden mean should be observed in this respect. Enough should be done to allow the average student to follow without too much loss of time, and not enough to relieve him of the responsibility of doing some good, hard work on the subject.

Again, in the transformation of equations there was often an opportunity to arrange the matter in a way to secure clearness. Sometimes, instead of an additional line showing that a certain quantity A was equal to another quantity M, it was possible, by placing one quantity directly under the other (M under A), to indicate the equality so clearly that the reading of the second line would suggest everything necessary. It was possible in this way to secure what might be called a clearer style, and to avoid unnecessarily diverting the mind of the student. Gain could be made in these two directions.

The Author writes that, since forwarding his manuscript, he has found a memorandum of the following point, which he had intended to include in his paper. In inserting letters in diagrams or figures, for purposes of reference, it is important to place the letters in such an order that they may be easily found. For example, if the point designated by *A* has been referred to, the letter *B* should be used to designate the point next to *A* in position or in relationship. Often much time is wasted in hunting over the face of a drawing for reference letters, which have been arranged without any order, and which seem to be playing hide and seek.

THE TRUE PLACE OF DRAWING AND SHOP-WORK IN ENGINEERING COLLEGES.

BY CHARLES H. BENJAMIN.

Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio.

Before this subject can be intelligently discussed, it is necessary to determine why drawing and shopwork are taught at all in a technical college. It has seemed best to consider these two branches together, since the same principles apply to both and the two are closely related both as educational factors and as practical pursuits.

The value of any form of manual training in cultivating the perceptive faculties, in giving better ideas of the forms and relations of objects, and in promoting habits of accuracy and exactness is now generally recognized. The value of drawing in stimulating the imagination, in training the memory and as a means of expression, is not for the engineer alone but for any man.

These are the reasons why drawing and carpentry and machine work should be taught in our public schools as a part of our general educational system. In the public schools the instruction in these subjects should be of such a character as best to present the educational side.

To a certain extent the same is true in the technical college. The fact that the work in the technical college is shaped by practical considerations does not deprive it of its educational value.

One great aim of every such school should be the training and development of the mental powers of its students, and those are the most successful teachers who can teach in such a way as to insure this.

But, after all, the real object of an engineering college is to supply a certain demand and the product which it turns out must be such as to satisfy the requirements. No doubt technical colleges have in the past created and shaped the demand to some extent, and may continue to do so. In general, however, manufacturers and employers know what they want and will not be moved to change their views by any theoretical considerations.

The most practical and economical methods in drawing and in manufacturing machinery have been determined by a long course of experience, with its successes and its failures, and from their very nature are not usually susceptible of theoretical demonstration.

If an engineer has found by trial of this and that way of making a drawing, or a pattern, that a certain way produces the best results in the least time and at the least expense, no amount of argument founded on theory will induce him to change that way. Instructors who have had actual shop experience outside of school are uniformly more successful in teaching these branches.

They should always keep in touch with engineers and manufacturers that they may understand the requirements of the profession and endeavor to meet them. The drawing and sometimes the shopwork for the first year is more of the manual training type, but early in the course the work should assume the characteristics of outside practice. We must not, however, lose sight of the fact that we are training engineers and not artisans.

I would give freehand drawing a prominent place, but would prefer to have it follow rather than precede the elementary mechanical drawing, and would make it a part of the course in machine design. Freehand drawing, when properly taught, is the higher type and requires more thought and more originality than mechanical.

Freehand sketches are the means which the engineer and the superintendent use to express their ideas, to make clear to customers, to their superiors, and to their subordinates, the designs which they desire to have executed. It is the mere draughtsman, the subordinate, who uses the line-pen and the T-square.

In teaching freehand drawing, it is best to begin with copying simple forms of machine details from the objects themselves, then to advance to more complex forms, drawing them both in orthographic projection and in perspective, following this with practice in drawing from memory after a careful study of the object, and finally teaching the students to sketch designs originated by themselves.

Following the principles already enunciated, the mechanical drawing should be taught in accordance with the current practice in the best shops of the country. In minor details the usages of various establishments may differ and it is well for the student to note these differences. For this reason it has been my practice to have the student work in the shop from drawings loaned by outside firms, and become familiar with the peculiarities of different draughtsmen.

For the same reason visits to the draughting rooms of leading manufacturers are very instructive.

The drawings may at first be copies from existing machines and then original designs, made on tracing linen or bond paper and then blue printed. When practicable, the designs should be useful ones which may be carried out in wood and metal in the shops, and then added to the school equipment.

It is well to have the students' design manufactured before he leaves the school, that the errors of judgment and execution which are sure to be found, may be pointed out to him. It is not for economical reasons that this manufacturing is recommended, but because it stimulates interest and insures better work. The drawing room should represent to the student the modern drawing office in discipline, in routine, and in its connection with other parts of the shop. The drawings should be classified, indexed, etc., as in actual practice, and the whole training be of such a character that when the student steps from the school office into the real office, he will not feel wholly out of place.

In the shop proper the same principle should be carried out. Manual training ought to be a condition of admission. If this is impracticable, the students who have not had such training should be in a class by themselves and be made to work extra hours until they can be classed with the others. The most important branches for the engineer to understand are molding, pattern-making, machine work and tool dressing. Joinery should be taught only to the extent necessary to insure accurate work in pattern-making. There is no place for cabinet work or fancy turning in a technical college, and the time can be used to a much better purpose.

The molding and pattern-making should go hand in hand, and should include as great a variety of work as possible, but it should be practical work, details of actual machinery. The principal reason for teaching these two branches to an engineering student is that he may better understand machine design.

As before suggested, it is desirable to have students work from the drawings of outside firms as well as those made at the the college, in order that they may become familiar with various styles of drawing.

In machine work, the writer would start the beginners on pieces of actual machines early in the course, in some cases making them pay for work which they spoil, not for economical reasons, but as a penalty for carelessness.

In the opinion of the writer, there is no question but that better results are secured by building complete machines either from students' designs or from outside drawings.

This method keeps up the interest and also trains the student somewhat in the constructive part of dedesign.

It may be necessary to employ a journeyman to do some of the work, or even to have it done outside, but the most possible should be done by the students.

It is well to have the students do a certain amount of tool-making and tempering, but there is little if any advantage in spending much time with filing, chipping and forging in a school of this kind, as these are mere handicrafts.

As in the drawing office, the discipline, methods, and routine, in fact the whole atmosphere of the college shop, should be that of a well-ordered modern manufacturing establishment. A good system of accounting for time and stock should be adopted and the men held rigidly to it. The check system should be used for tools and the men held accountable for their good condition and safe return.

The students should be treated as responsible beings and dealt with as men are dealt with in other shops, loud talking, singing etc., being discouraged, and no loafing by workmen or visitors allowed.

This argument for a practical shop, in contrast with a toy shop, is not based on any consideration of dollars and cents. The writer never has known a piece of machinery built by students that did not cost the college more than its market value. But he believes that the only way to give young engineers the necessary familiarity with shop practices and methods is to make the college shop a real shop where work is done as in outside establishments.

Educators differ widely as to the amount of time that should be given to hand work in an engineering college. Five hours a week for two school years will give a student who has already taken the course in manual training, a pretty clear idea of pattern and machine work.

He need not entirely sever his relations with the shop even in his senior year. Any designing or original investigation may keep him in touch with shop methods, although he may not do the shop work himself. The importance of these coördinate branches of drawing and shop work can hardly be over stated.

Experimental investigation in the mechanical laboratory is a valuable aid in imparting information and in training the mind, but comparatively few have an opportunity of continuing such work after leaving college or of making any practical use of it. For the mechanical engineer, machine design is the all important study in the majority of instances, and the great demand is for young men who are capable of designing and constructing improved machinery in accordance not only with correct mechanical principles, but with modern shop practice.

Discussion.

Prof. H. W. Spangler disliked to discuss this paper which put things so differently from what he believed to be correct, but would say a few words. At the end of the paper it was said that machine design was the principal thing. He wondered if the author knew that sixty per cent. of the graduates of engineering schools had no more to do with the machine design than with artesian well boring? He felt confident that in a narrow sense of the word, as used by the author, machine design was not of much use. The manager and brains of one of the largest tool concerns in the country has said to him "Give me men who can use their hands, and chip and file, instead of attempting to teach them the use of machine tools." This man was putting it from his point of view; but to the speaker's mind a large part of the time spent over machine design and the use of machine tools was time wasted. This subject was taken up a little more fully in the paper which he was to read Tuesday, but he disagreed with the author about his mechanical draughting, and perhaps for the following reason: It had been the speaker's lot to teach a class of draughtsmen the principles of machine design, and at the close of the course he had asked the class to examine his university students' work. A gentleman who was in charge of one of the largest drawing rooms in Philadelphia, after inquiring into the system used, claimed that it was all wrong. As was to be expected, he outlined a course which he himself had in operation. His method was good under his own conditions. The speaker asked how long it would take to take young men through such a course satisfactorily. The answer was, about two years. He was asked if he could do it in ninety hours? He would not believe it could be done in that time until he was shown what men had accomplished in that time. It was purely mechanical to be sure, teaching them to draw and not to design. So far as shop practice went, the shop practice was to make blue-prints. Now it seemed to the speaker that the shop method of doing machine work was an entirely different thing from what should be done in technical schools. They didn't teach a boy in the machine shop to finish a machine, but he spent weeks and weeks in cutting bolts, and that sort of thing, and that is what he wanted to get far away from. In other words, the effort should be to teach, not processes, but principles. It was well understood that men did all sorts of mechanical processes with absolutely no knowledge of the principles underlying them. It was therefore not necessary that principle and practice should go together to the extent that Professor Benjamin seemed to advocate in his paper.

Prof. John M. Ordway remarked that the paper seemed to have assumed that the only woodwork was pattern making. But there were many machines with wooden frames. Should not something be learnt about the joints of those frames, and all that sort of things?

Prof. Milton P. Higgins when called upon by the President was pleased to say a few words, though merely a visitor and not a member of the Society. The paper impressed him as a very reasonable and practical consideration of the subject. The course outlined by Prof. Benjamin was quite similar to that adopted and followed at the Worcester Polytechnic Institute, where he had been superintendent of the shops for the past twenty-six years, since its organization. In a college for mechanical engineers, workshops of some kind and character are now generally deemed an essential; but there seems to be a great diversity of opinion regarding the kind of shop and the method of conducting it for the most effective instruction of the student.

At Worcester the shops are organized and conducted on a purely business basis. A large amount and a great variety of machinery is designed, constructed, sold and operated, in competition with all the best builders of machinery. This machinery is constructed by students and skilled mechanics, working in coöperation with each other. It has been found desirable and profitable to have one-third as many employed workmen as there are engineering students. Men of various grades, both skillful and unskillful, work with the students, so that only the necessary and desirable amount of the elementary work of the shop is required of the student. There are men suited to do all the drudgery, except that which is beneficial to the student. On the other hand, the advantage of having many skilled workmen is obvious, in order that the student may work in very close contact with men of superior skill and experience upon the most important and difficult parts, which the student could not well accomplish alone at the beginning of his course. Only the first part of the course should be confined to mere sample parts of machinery, samples of machine work or sample exercises; but it is desirable to build complete machinery, not only fine, small machines, but some larger and heavier machinery, introducing as much variety of difficulties to overcome as possible. It is well to confine the practice to work of a thoroughly practical kind, avoiding all fancy work, and notional, experimental constructions.

At Worcester, with 200 students taking shop practice in coöperation with 60 men, a large variety and amount of product is the result. There, it has been found practicable to build machinery fit to stand the practical test in actual service, which is in demand by the buyers of the best machinery, a large amount being sold each year. After twenty-six years of this experience, it is generally agreed that there is great advantage to the engineering college in disposing of the products in the ordinary way, because if a machine is made in such a manner that it costs too much, it is not a success as an engineering and manufacturing enterprise. Therefore the question of comparative costs is ever before the student, and the test of putting a thing on the market to be bought and paid for in open competition with all makers and users, is most healthful and helpful in freeing the students and professors from error and conceit.

The Worcester plan has been, through all its experience, a most emphatic demonstration of the practical plan so clearly outlined in the paper of Prof. Benjamin, and during all these years there has been no faltering or lack of faith in this system by those intimately acquainted with it, but the conviction has been growing that the greatest possibility of improvement lies along this commercial method of shop practice, and all that is good in any other system of shop practice can best be realized in a practical, productive shop.

GRADUATION, THESIS, AND DEGREES.

BY STORM BULL.

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The papers by Professor Ricketts, Swain and Thurston, on the question of Engineering Degrees, read before the Society at the Brooklyn meeting, aroused at the time of the reading quite a little discussion, the report of which, however, unhappily was lost. As the views of the writer on the subject do not coincide with those expressed in either of the papers, he has thought that it might not be out of place to return to this subject once more, and then take it up more particularly in its connection with the Thesis and Graduation.

Probably most engineers and even teachers in engineering colleges do not consider their engineering degrees of any great value. To many, therefore, it might seem superfluous to spend so much time on this question of degrees; at the same time, everybody should see that the fact that so many different kinds of degrees are given at graduation in engineering colleges is a misfortune so long as any value is placed on the degree; and it is no doubt true, that to a young engineer the professional degree is of some value, so that if possible the degrees given at the completion of a four years courses in engineering colleges should be the same.

Professor Thurston seems to think that there are at least two kinds of engineering colleges, and that it is only correct to give a degree of C. E., etc., when graduating from a college of the one kind, and a bachelor's degree when graduating from a college of the other kind. It seems to the writer that it is entirely out of the question to divide the colleges in this way. Who is going to do it, except the authorities of the colleges themselves? It is only natural to suppose that the colleges at which the requirements are the lowest will not be willing to advertise themselves as such by giving a lower degree than other colleges give. The argument of Professor Thurston should, of course, also hold for all other degrees given by the various institutions of learning. Certainly a bachelor's degree from Harvard University does not stand for the same amount of knowledge acquired, as the same degree from one of the new western universities.*

It seems therefore to the writer that the argument for giving two or more kinds of degrees from the various colleges is a very poor one, and that the only real question is whether a bachelor's degree, or the professional degree, should be given at graduation. There are comparatively few professional engineering colleges in the United States which are not carried on in connection with some university, and it would therefore seem to be correct to look at the question from the standpoint of those colleges which are connected with universities, from which institutions students graduate with various kinds of bachelor's degrees. Because the professional colleges, which are not connected with universities, are altogether the exception in this country, they should be willing to conform to the practice in other engineering colleges, or to adopt those rules for graduating degrees which are found to be best adapted for the majority of engineering colleges. It is quite possible that considering Stevens Institute of Technology alone, it might seem best to give the professional degree upon graduation, and on the other hand, it might not be the best for Sibley College at Cornell, but both ought to give the same degree. The author of this paper is decidedly of the opinion that the bachelor's degree should be given, and his reasons are as follows:

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* Some of the reasons given by Professor Thurston for preferring to give the professional degree at graduation seem rather curious, especially the one that the students prefer the professional degree to the bachelor's degree. This is no reason; it is evident that a student prefers the higher degree, which is at the same time professional, to that of the bachelor's degree, and I suppose if they had the choice of taking the doctor's degree in the same way, they would prefer it to both the bachelor's and the professional degree.

In nearly all engineering colleges the time required for graduation, when a student enters the Freshman class, is four years, the same time as is required for the various bachelor's degrees in other lines of study. The requirements for admission, almost without exception, are substantially the same for engineering Freshmen, as for Freshmen in the academic departments of the university. I do not mean by this statement that the studies required for admission to a classical course are the same as to one of the engineering courses, but that the total amounts of preparatory work are nearly equivalent for the various courses. The degrees granted at graduation should, therefore, be equivalent,—the degree granted to a graduate in mechanical engineering should be equivalent to the A. B. granted to the classical student. It seems to the writer that only a bachelor's degree can be the equivalent of a bachelor's degree: the degrees C. E., E. E., etc., are purely professional degrees, and always give the impression of being the final degree, not the first degree. It is of course true, that the students in medicine obtain their professional and final degree at graduation from the school of medicine, but it should be remembered that the original idea certainly was that a candidate for the degreee of M. D. should already have the A. B. degree. Such is the case in France and various countries of Europe. In Germany apparently this is not the case; but the student when entering the university or the polytechnic school has already obtained the gymnasium diploma which is not very far from being equivalent to a bachelor's degree. In the Scandinavian countries, the bachelor's degree is required before the student can begin the study of medicine, law, etc. It should be required in this country, and it is only because we are a young people that such a requirement cannot be made at present. The time will come when the various colleges of medicine will insist on such preparation for entrance. The engineering students are therefore very far from being on the same level with the medical student, and an argument derived from the medical college is not applicable to the engineering college. At present the studies taught in the engineering colleges are partly professional, partly scientific, and partly literary. The professional studies may certainly be classified with those of applied science, and for this reason it seems but natural to give the degree of bachelor of science to the graduate. If some time in the future it shall be found possible to eliminate everything of both purely scientific and literary character from the curriculum of the engineering college, and require a bachelor's degree of all entering students, then it might be wise to give the professional degree to graduates in engineering. But this is only a very remote possibility which need not concern us at present. Prof. Thurston in his paper speaks as if the requirements for Sibley College were now of such a nature that nothing but professional studies were left in the course. This certainly is an error as both calculus, physics, chemistry, mechanics, etc., are left in the course, and these are certainly scientific and not professional studies. It is of course useless to hope that some time in the future the preparatory schools will give these studies, and so make it possible for the engineering colleges to drop them from their course of studies. These studies will always remain university studies, and if they should not be taught in the engineering colleges, the young man who aspires to become an engineer would have to take a general course at the university before entering the purely professional college of engineering. As it is now, every course in engineering in the various engineering colleges of the United States contains non-professional studies to a greater or less degree, and so long as this is the case the writer is of the opinion that only the bachelor's degree should be given.

A second reason for giving the bachelor's degree is found in the fact that a graduate from an engineering college as organized at present is not yet an engineer. He needs both experience and continued study before he can be trusted with an important piece of engineering work. All engineering educators, as well as all practical engineers, know this to be a fact, and it therefore seems much more correct to withhold the professional degree until the graduate has proved in actual practice that he is worthy of a professional degree. This part of the subject was treated very fully by Professor Swain, our worthy President, in his paper read at the Brooklyn meeting, so that it seems unnecessary to say more about it here. However, this point leads to a second part of the subject of this paper, the question of thesis. The nearly universal practice in engineering colleges is to require a thesis for graduation. This thesis should of course to some degree test (1) the student's ability in the direction of original investigation, (2) his self-reliance and (3) the knowledge he has acquired during his four years course. It is however impossible to make such a test thorough enough to enable the teacher to judge whether the young man has the necessary qualifications for making an engineer. First of all, such thesis work is always done under the direct supervision of the teacher. To a greater or less degree, the teacher leads the students, tells them what to do, and it is therefore not independent nor original work, the capacity for which is a prerequisite for an engineer. Secondly, from the very fact that the teacher is always helping, the self-reliance of the student is very often only tested to a very limited degree, and this quality is a necessity for a man who is worthy of receiving the professional degree. As to the third point, the thesis no doubt furnishes a fairly good test, but such a test is already at hand in the ordinary examination, and is therefore of minor value. The point which the writer has attempted to make here is that the graduation thesis is not a sufficient criterion for granting the professional degree. On the other hand, there cannot be a doubt that the thesis, as a part of the instruction in the engineering college, is of very great value, and that as much stress as possible should be placed upon it. The subject of the thesis being well selected, the work required for writing it should be at least as profitable to the student as any other study pursued during the whole course. It is an entirely different matter when a thesis is required for the professional degree after graduation. The rule for the sequence of the professional degrees at the University of Wisconsin, with which the writer of this paper is connected has for some years past been as follows: The degrees of C. E., M. E., and E. E., are conferred as second degrees upon bachelors of science in the civil, mechanical and electrical engineering courses respectively, who (1) pursue advanced professional study at the university for one year, and present a satisfactory project or thesis; or (2) present suitable evidence of three years of professional work of which one must be in a position of responsibility, together with a satisfactory thesis.

As will be seen, these rules require of a non-resident that he shall have had three years of practical engineering experience, and that he shall have held a responsible position during one of these years; and in addition to this, a thesis which must be satisfactory to the faculty. These requirements are sufficient to warrant the award of a professional degree. First of all, the thesis is here independent work, and therefore a good test of the capacity of the man; secondly, the requirement of the employment of the candidate in a responsible position for one year makes it perfectly certain that he is capable of doing such work as a man holding the professional degree should be capable of doing. As will be seen from the rules quoted above, a post-graduate student may obtain the professional degree after one year of study at the university, if he presents a satisfactory thesis. It is the opinion of the writer that this is not so good a test as that required for non-residents. However, it is true that a thesis submitted by a graduate student should be an original and independent piece of work. The objection is that the candidate has not yet shown his capacity for practical work, except in the case of his pursuing his profession between the time of graduation and his entrance upon his post-graduate studies. But it must not be overlooked that the faculty who are to recommend the candidate for a degree are then in a very much better position to judge as to the qualifications of a candidate than at the time of graduation.

The rules given above can no doubt be improved, and they have been quoted here partly for the purpose of inviting discussion. The main point which should be emphasized, is that the graduate of an engineering college should receive a bachelor's degree, and that a professional degree should be granted only after a certain lapse of time, in which the candidate has had opportunity to show that he can do independent and important engineering work.

It seems to the writer to be a matter of small importance which bachelor's degree is given at graduation. In institutions like Leland Stanford Junior University, where otherwise only one bachelor's degree, that of A. B. is given, it is but natural that the engineering graduates also should receive that degree. But in institutions where several bachelor's degrees are given, it seems to the writer that the B. S. degree is the best. The course of study which the engineering student pursues is mainly one of science, and if the degree is to be at all indicative of the line of study, Bachelor of Science certainly is very appropriate. It would of course be very desirable to have only one bachelor's degree used for graduates of engineering colleges; but this is of comparatively small importance, and it is not probable that this can be accomplished in the near future, if at all.

If Bachelor of Science is used, it seems desirable to specify in which special line the student has worked. In many institutions this is done by adding "in Civil Engineering," "in Mechanical Engineering," etc., to the Bachelor of Science. The abbreviation of the degree would however still remain B. S., and the addition would be used only when writing the degree out in full. The diploma would give it in this way, so that if an engineering graduate should want to make use of the diploma for procuring a position, it would show the specialty to which he had devoted himself, and in which therefore he should be most competent to do work.

The reasons why the writer does not favor the use of Bachelor of Civil Engineering: B. C. E., etc., have been stated in part by Prof. Swain in his paper. It may be added, however, to the argument given in the last mentioned paper, that if such a degree is used, the second degree should logically be Master of Civil Engineering, M. C. E., a degree which is both clumsy and has no tradition behind it, and to which the C. E. is very much to be preferred.

It need hardly be pointed out that an engineering graduate who does not follow his profession but turns his attention to purely scientific subjects, should as his second degree receive M. S., Master of Science, and not a professional degree.

The writer does not see any serious objection to a third degree. There is, however, a slight difficulty in determining what the degree should be. The choice lies between Doctor of Engineering and Doctor of Science. If this third degree is to be regarded as a professional one, then there can be no doubt but that the first one mentioned should be preferred. In addition, the writer thinks that it would not be quite the proper thing to give the title of D. S., except to a person who, besides fulfilling the requirements for the degree of Doctor, has also fulfilled the requirements for the Master of Science degree, and that would probably not be the case with engineering candidates for the doctorate. On the other hand, it does not seem quite correct to give a person the degree of D. E., if it is not for purely professional work. However, taking everything into consideration, it seems that Doctor of Engineering should be preferred.

DISCUSSION.

PROF. JOHN B. JOHNSON remarked that although the responsibility for this paper had been placed upon his shoulders, the burden had now been removed, and all would agree with him that it was well to have it as a summing up and review of the long discussion had last year, which however still left us "in the air," as the discussion had been unfortunately lost. The position taken by the writer in this paper was one which he agreed with and endorsed heartily, and he had advocated it for his own institution and he thought he would continue to do so until successful in it.

PROF. GAETANO LANZA, referring to the question of the professional degree, thought that all that a college can assert in a degree is that the student has done in a satisfactory manner the work laid out and assigned, but that it should not go beyond that point. It would therefore be wiser for the college to stop there, and to give for its first degree S. B., and only such advanced degrees as M. S. or Ph. D. The difficulty with the professional degree is that it is not clear whether it is a college degree, a business card, or what it really is; but with the title M. S., etc., everybody knows that it is a college degree.

He was, therefore, thoroughly in sympathy with most of what was said in the paper, but it seemed to him wiser, on the whole, for the college to let the professional degree alone.

PROF. JOHNSON called attention to the fact that the program of this meeting was prepared for the purpose of considering what is now immediately practicable in the line of improving education in this country. Instead of proposing what is ultimately possible, or even desirable, it would be more profitable at these meetings, year after year, to consider that which could be immediately utilized. We may ultimately come to the position which Prof. Lanza has indicated; but the custom has been to confer degrees covering four years courses. We are now in a transition stage; we are moving away from it, and the question now is what can be recommended for the Faculties to do next year. The speaker believed that it would be proper to recommend that a certain amount be done now, and after awhile we can get to the position which Prof. Lanza has outlined. that the college should be responsible only for what is done inside its walls, and that the college degree should have a scholastic significance simply. The degress are now very commonly given, and it is astonishing to see how many ways there are of graduating students and conferring degrees. At Washington University there are no means of conferring professional degrees except at the end of the fifth year for resident study; but the speaker believed that such a condition as is imposed by the writer of the paper, three years of work one of which is in a responsible position, coupled with a satisfactory thesis, is a better basis for conferring a professional degree than a fifth year of study in the college, if it is to be done at all. He believed that such a position is a step in advance, until the professional degree is dropped altogether. The following table shows the present (1895) practice of many of the engineering colleges in the way of conferring degrees.

Engineering Degrees.

COLLEGE.	Professional Degrees at end of 4 years.	Not giving Professional Degrees at all.	B.S. *or* Equiv. in 4 years. with Professional Degrees **only** after 1 year of resident study.	B.S. *or* Equiv. in 4 years. Prof. Degree **either** after 1 year's residence or on some non-resident condition.
New Brunswick		+		
Thayer			+	
Univ. Vermont				+
McGill				+ *
Mass. Inst. Technology		+		
Tufts				+
Worcester		+		
Harvard		+		
Brown	+			
Yale			+ *	
Columbia				
Univ. City of N. Y.		+		
Brooklyn Polytechnic		+		
Union			+	
Rensselaer	+			
Cornell	+ *			
Toronto				+ *
Stevens	+			
Rutgers				+ *
Princeton	+			
Delaware				+ *
Univ. Pennsylvania				+
Swarthmore				+ *

*For details see pages 152–153.

ENGINEERING DEGREES.

COLLEGE.	Professional Degrees at end of 4 years.	Not giving Professional Degree at all.	B. S. or Equiv. in 4 years, with Professional Degrees only after 1 year of resident study.	B. S. or Equiv. in 4 years. Prof. Degree either after 1 year's residence or on some non-resident condition.
Lafayette	+			
Lehigh	+			
Pa. State College				+
Univ. Western Pa.	+			
Columbian			+	
Univ. Virginia	+ (?)			
Univ. of W. Virginia		+		
Ala. Polytech. Inst			+	
Ky. State College	+ *			+
Vanderbilt			+	
Cincinnati				+ *
Case School				+ *
Ohio Univ.	+			
Purdue				+
Notre Dame	+			
Rose Polytechnic			+	
Armour Inst.				+
Univ. Illinois			+	
Univ. Wisconsin				+
Univ. Michigan				+
Mich. Mining			+ *	
Univ. Minnesota				+
Univ. Iowa				+

*For details see pages 153–155.

Engineering Degrees.

COLLEGE.	Professional Degrees at end of 4 years.	Not giving Professional Degree at all.	B. S. *or* Equiv. in 4 years. with Professional Degrees only after 1 year of resident study.	B. S. *or* Equiv. in 4 years. Prof. Degree either after 1 year's residence or on same non-resident condition.
Cornell College			+ (?)	
Washington Univ.			+	
Univ. Missouri				+
Ark. Indust. Univ.				+ *
Tulane			+	
Univ. Texas	+			
Univ. Kansas			+	
Univ. Nebraska		+		
Univ. Colorado		+		
Colo. Sch. Mines	+			
Univ. California			+ * (?)	
Leland Stanford Jr.			+ *	

*For details see pages 155–156.

Degrees for Engineering Courses.

College.	First Degrees.	Second Degrees.
Univ. New Brunswick. Cat. 1894.	Diploma in C. E. in 4 years.	None.
Maine State College. 1894.	B. C. E. B. M.E. for 4 years.	C. E. M. E. After 3 years professional work — an original thesis.
Thayer School........ 1893–4.	B. S. at end 4 years, if 3 years are in Chandler school, and 1 year in Thayer school.	C. E. at end of additional year in Thayer school, or at end 2 years in Thayer, wherever the student comes from.
N. H. Agr. College..... 1893–4.	B. S. for 4 years.	"Advanced degrees for appropriate work."
Univ. of Vermont..... 1893–4	B. S. in C. E. " " M. E. " " E. E. for 4 years.	C. E. M. E. E. E. 1 year in residence *or* non-resident study for 1 year, — 1 year of professional work. The course of non-resident study to be approved in advance. Professional theses at the end of the 2 years. Detailed statements of professional work required.
McGill Univ........... 1894–5	B. Applied Science in C. E., E. E., M. E., Min. E., Pract. Chem.	Master of Eng. C. E. E. E. M. E. Mining, 3 years, bona fide book work with examination on general theory and practice, *or*, a graduate course — 2 year's professional work.
Mass. Inst. Tech....... 1893–94.	B. S. for all courses.	M. S. 1 year resident study.
Tufts 1893–4	B. C. E., B. E. E.	C. E. E. E. 1 years residence — thesis *or* 3 years prof. work, one of which must be in responsible place.
Worcester .... 1894–5.	B. S. for all courses.	None shown in catatogue. Offers 5th year in Elect. Eng.
Harvard .... 1893–4.	B. S. for all courses.	No professional degrees to S. D.
Brown .... 1894–5.	C. E. M. E. for 4 years.	None.
Yale .... 1893–4.	B. Ph. for 3 years.	C. E. M. E. 1 year resident study and 1 year professional work under supervision of the school. Original design or project with detailed drawings and full descriptions.
Columbia		
Univ. City of N. Y..... 1894–5.	B. S. for C. E.	None.
Brooklyn Polytech.. 1894–5.	B. S. in Engineering.	None.

Degrees for Engineering Courses.

College.	First Degree.	Second Degree.
Union 1893–4.	B. E. for C. E.	C. E. 1 year resident study. Course prescribed.
Rensselaer 1894.	C. E. for 4 years.	None.
Cornell 1894-5.	C. E. M. E. B. S. in Agr. B. S. in Arch. 4 years.	Master of C. E. " " M. E. M. S. in Agr. 1 year resident study and thesis, *or* 2 years practice and non-resident study. M. S. in Arch. 1 year resident study and thesis. A 5th year for Marine Eng., probably leading to M. M. E.
Univ. Toronto 1894-5.	Diploma at 3 years from Sch. Prac. Sc.	B. Ap. Sc. 1 year residence at Univ. of Toronto, *or* C. E. 3 years prof. work with 2 of them in construction or operation of works + thesis accompanied with plans, estimates, specifications, etc., + examination on professional work.
Stevens 1894–5.	M. E. in 4 years.	None.
Rutgers 1893–4.	B. S. in 4 years	C. E. 3 years practice and study + professional thesis.
Princeton 1894–5.	C. E. in 4 years.	E. E. 2 years prescribed course in Elect. Eng.
Delaware 1893.	B. C. E. B. M. E. B. E. E. in 4 years	M. E. C. E. E. E. 3 years prof. work + prof. thesis.
Univ. of Pa. 1893–4.	(Has two schemes.) B. S. in 4 years. 2d plan B.S. in M. E. B.S. in E. E. B.S. in C. E. in 4 y'rs	M. S. for 5th year, with M. E., C. E., E. E., with 2 years prof. work + thesis. M. S. *and* M. E. E. E. C. E. 3 years prof. work + thesis.
Swarthmore 1894-5.	B. S. in Eng. in 4 years.	C. E. 3 years practice + thesis.
Lafayette 1893–4.	E. M. E. E. C. E. B. S. in Chem. B. S. Gen'l Sc. in 4 years.	M. S. 3 years collegiate or professional study and practice + thesis, *or* 1 year residence and 1 year practice.
Lehigh 1893–4.	C. E. M. E. E. E. A. C. B. S. in Arch. B. S. in Mining. B. S. in Metall. in 4 y'rs.	E. M. 1 year resident study course prescribed. M. S. 1 year's residence study *or* 2 years in absentia + thesis.
Pa. State College 1894.	B. S. in course 4 years.	C. E. M. E. E. M. E. E. M. S. 1 year's study + thesis ½ to major ½ to minor, *or* 3 year's professional work + thesis.

Degrees for Engineering Courses.

College.	First Degree.	Second Degree.
Univ. of West Pa. 1893–4.	C. E. M. E. E. E. } in 4 years.	None.
Columbian. 1894.	B. S. for all courses in 4 years.	C. E. E. E. } 1 year residence + thesis.
Univ. of Virginia. 1894–5.	C. E. (?)	
Ky. State College. 1893–4.	C. E. B. M. E. } in 4 years.	M. E. 1 year residence + thesis *or* 3 years professional work + thesis.
Vanderbilt. 1894–5.	B. E. in 4 years.	C. E. M. E. E. M. } 1 year residence + 3 months practice. 5th year in catalogue part, prescribed, part elective.
Cincinnati. 1893–4.	B. S. in C. E. in 4 years.	C. E. on proof of ability to design and direct engineering works of importance + thesis.
Case. 1894–5.	B. S. in all courses.	M. S. 1 year residence + thesis. E. E. M. E. C. E. E. M. } 1 add. year resident study above M. S. + original thesis, or technical report, *or* 3 years professional work after B. S. + original thesis or technical report.
Ohio Univ. 1894–5.	C. E. E. M. M. E. } in 4 years.	Doc. Sc. 3 years resident study and original thesis.
Purdue. 1894–5.	B. C. E. B. M. E. B. S. } in 4 years.	M. E. C. E. A. C. or M. S. } 1 year resident study + thesis entire time in speccialty, *or* 3 years professional work + examination. Chemists must be in residence. M. S. for other science courses.
Notre Dame Univ. 1893–4.	C. E. M. E. } in 4 years.	None.
Rose. 1894.	B. S. for all courses in 4 years.	M. S. after 2 years, one of which is given to an approved course of study. M. E. E. E. C. E. } After M. S. 2 years professional work and thesis or report.
Armour. 1894–5.	B. S. in M. E. B. S. in E. E. B. S. (for Chem.) } in 4 y'rs.	M. E. E. E. } 1 year residence *or* 2 years professional work.

Degrees for Engineering Courses.

College.	First Degree.	Second Degree.
Univ. of Illinois...... 1894–5.	B. S. in course in 4 years.	C. E. M. E. E. E. Mast. Arch. 1 year residence + thesis on original research, ⅔ of work in primary topic, ⅓ in secondary.
Univ. of Wisconsin.... 1894–5.	B. S. in Eng. in 4 years.	C. E. M. E. E. E. Min. E. Met. E. 1 year residence + thesis, *or* 3 years professional work (1 in responsible position) + thesis.
Univ. of Michigan.... 1893–4.	B. S. for all courses in 4 years.	C. E. M. E. E. M. E. E. 1 year in residence or its equivalent + 1 year professional work. If non-resident, a professional thesis.
Mich. Mining School.. 1895–6.	B. S. in 3 years. 1 year = 45 weeks.	E. M. 1 year prescribed study.
Univ. of Minn......... 1894-5.	B. C. E. B. M. E. B. E. E. B. Min. E. B. Chem. E. B. Met. E. in 4 ears.	C. E. M. E. E. E. Chem. E. Min. E. Met. E. or M. S. 1 year residence + thesis *or* 2 years non-resident study + thesis.
Univ. of Iowa......... 1893–4.	B. S. in C. E.	C. E. 1 year residence *or* 3 years professional work + thesis.
Cornell Col. (Iowa).. 1894–5.	B. S. in C. E.	M. S. or C. E. Resident study and thesis?
Washington........... 1894-5.	B. S. in course in 4 years.	C. E. M. E. E. E. E. M. M. S. 5th year's work prescribed for each course.
Univ. of Mo............ 1894–5.	B. S. in course.	C. E. E. E. M. E. 1 year residence + thesis, *or* 2 years practice and non-resident study + original thesis.
Ark. Indust. .... 1893.	B. C. E. B. M. E. B. E. E. 4 years.	C. E. M. E. E. E. 3 years professional work + thesis.
Tulane .... 1894–5.	B. E. for all courses in 4 years.	"Appropriate engineering degree" for resident study only.
Univ. of Texas........ 1893–4.	C. E. in 4 years.	None.
Univ. of Kansas....... 1894–5.	B. S. in all courses in 4 years.	C. E. 1 year residence. None for other courses.
Univ. of Nebraska ... 1894–5.	B. S. for all courses in 4 years.	None. 1 year graduate work in Elect. Eng.

DEGREES FOR ENGINEERING COURSES.

COLLEGE.	FIRST DEGREE.	SECOND DEGREE.
COLO. SCH. MINES ...... 1894–5.	C. E. E. M. E. E. B. S. (for Chem.) in 4 years	None.
UNIV. COLORADO .... 1893–4.	B. S. in C. E. B. S. in E. E. in 4 years	None.
UNIV. OF CALIFORNIA.. 1892–3.	B. S. for all 4 year courses.	M. E. Min. E. Met. E. C. E. 3 years after B. S. Examination on subjects prescribed + 1 year professional work + professional thesis.
LELAND STANFORD, JR..	B. A. for all 4 year courses.	"Engineer" 1 year work + thesis, probably resident study.
ALA. POLYTECH. INST.. 1895.	B. S. for all 4 year courses.	Min. E. C. E. E. E. M. E. 1 year residence.
UNIV. W. VIRGINIA .... 1894-5.	B. S. in course C. E. B. S. in course M. E.	M. S. 1 year residence. (?)

PROF. BULL would be very glad, if it were possible, to have no professional degrees given.

PROF. THOMAS GRAY agreed very thoroughly with Prof. Bull in regard to the degree at the end of the four years' course. That degree is simply a certificate that the student has taken the regulation course of study. The class of students in any one year who receive that degree must, of necessity, be very far from uniform. A large number of them are, undoubtedly, unfitted to be classed as professional men. Very seldom are any of them found to be so qualified. The speaker would go even further in regard to the post-graduate degree. The first post-graduate degree at least ought to be also an academic degree, but it ought to contain some evidence of professional work, and it ought to be given after not less than two years of partly professional and partly practical experience. A professional degree should be given after the candidate had shown evidence of his ability to conduct professional work. Such a degree should be founded not simply on a period of years, but on something done. Some limit ought to be made, of course, to the length of time during which a candidate had practiced, and he would prefer that the lower limit should be three years, putting the professional degree at five years after graduation. This would put the time very much further along, but the degree would then be stamped with a great deal more value than at present. It is, in his opinion, very unfortunate to have a number of institutions giving degrees which, on the face of them at least, appeared to have professional value. He agreed, also, that the notation of professional degrees is unfortunate. For a long time all professional men used the title C. E., M. E., etc. That has given rise to one of the great objections to college study in the early days of colleges of engineering. Professional men dislike very much the practice of those colleges in incorporating the professional title, which a man who had spent anywhere from seven to ten years in practical work had adopted. It becomes unmeaning. There is a great deal in that objection. He was very strongly of the opinion that colleges are not fitted to prepare professional men. They can give them the preparation to begin, but they can not give them experience. What is wanted is a combination of the two. Let the colleges prepare the men, and then wait to see what they do with that preparation before they stamp them as professional men.

PROF. S. N. WILLIAMS understood from the paper that the recognized abbreviation is B. S. for Bachelor of Science in Civil Engineering, and wished to inquire if there is any dissent from that.

PROF. BULL stated that understanding to be correet.

PROF. DOOLITTLE, though not a member, would like to ask Prof. Bull, whether he could give any idea as to the proportion of students who take the preliminary degree at his institution, who afterwards receive the professional degree in one way or another.

PROF. BULL was unable to say off-hand, but thought perhaps one-half of those who undertake to do it succeed. This did not mean that only half of them pursue a profession, but only that so many take the trouble to obtain the professional degree.

PROF. F. O. MARVIN stated that the practice of the institution with which he was connected is, perhaps, a little out of the usual order. There are in the College of Arts courses which lead to the degree of B. A. That leaves B. S. for the engineering degree. The B. S. graduate then has open to him three other degrees. The professional degree of C. E. is only given after one year's residence. That is tentative, not satisfactory, and will be changed probably to something more in the line suggested by Prof. Bull. There is open, also, the second degree of M. S., provided the technical graduate makes good some further undergraduate work and takes a line of study not exactly in engineering, but in science. There will be open within a year or two, the degree of Ph. D. for the B. S. graduate. This was spoken of simply as showing what perhaps is the tendency, to a limited extent, in some of the colleges.

Prof. William G. Raymond referred to a point that Prof. Bull maintained, if his memory served, to the effect that the graduating thesis is usually an example, or an investigation of some sort worked out under the direction of the instructors, and not an entirely independent piece of work. That may be right, but he would like to know what is the general practice. In the school with which he was connected the practice is entirely different. Formerly the thesis was a review, but at present and for a number of years past, the graduating thesis has been an absolutely independent piece of work. The student is not allowed assistance, at least from the instructor; the plan has seemed to work very well, and there have been produced some very excellent designs which have been complimented by eminent engineers as being designs that would do credit to any engineer. It is of course understood that a student is not competent to design a piece of work in every detail without errors, but it is also true that there are a great many practicing engineers in the same condition, who would hesitate probably to admit that they were not competent to make the design. He believed that for a graduating thesis, particularly when a professional degree is given, as is the case in their school, an independent design is of really more value to the student than if he were under the direction of the instructor. If the design is unsatisfactory he did not graduate; and it seemed to the speaker that, being thrown thus on his own responsibility, the student has to do an amount of work and of independent thinking and investigation that is of very great value to him.

Prof. Mansfield Merriman was glad that Prof. Raymond had called attention to this subject. His own practice had been to regard graduation theses as a part of the examination for the degree. The student receives very little assistance from his instructors or professor. The subject is approved by the professor in charge, and the student is assisted to the extent of referring him to articles or books from which he may get information, and in the way of general outlines of treatment. The thesis, when it comes in, is examined and reported upon as a part, it might be said, of the final examination for the degree.

Prof. Bull felt that Prof. Raymond's statement as to the manner in which the thesis is prepared at the Rensselaer Polytechnic was quite different from the way which the writer had indicated. Prepared in the way indicated by Prof. Raymond it would be independent work, and, so far as that went, it would test the student. At the same time he doubted very much whether if a student presented a thesis which was not quite up to the standard he would lose his degree. He questioned that very much. In most institutions, if the examinations, with that exception, were passed by him satisfactorily, he would, the speaker believed, get his degree.

Prof. Lanza believed that examinations were a necessary evil, and that he hoped to get rid of them some time, and for one did not want them added to.

Prof. Merriman replied that the only sense in which he used the word examination was that the thesis shows the ability of the student to apply what he had been studying during the four years' course.

If the thesis shows that ability, it should be accepted; if not, it should be rejected, and in that sense of course it is a part of the final examination.

Prof. C. Frank Allen raised the point that if the work of the engineering colleges is a work of education, it seems questionable whether a considerable amount of time ought to be given to work which does not have the character of instruction, and on which instruction was not given. So far as a test of the student's work is concerned, the thesis is something in the nature of examination. In many of our colleges, a student is rated on his term's work, as well as upon his examination; this is a proper regulation, and the speaker saw no reason why the student could not be measured as well by the information which he seemed to think it necessary to obtain from the instructor as from the result which he reached without any such assistance. It had, however, occurred to the speaker that, while he entertained these views, it was his own practice to leave the students very much alone in the preparation of theses. It was not his personal practice to interfere with them to any considerable extent, but there did seem to be some advantage in allowing them to gain from their instructors whatever they found necessary in the way of instruction.

Mr. William Kent stated that at an alumni meeting which he attended some years ago the subject announced in advance was "Theses," and one of the professors gave a long argument as to why they should be done away with; but the almost unanimous feeling of the alumni was on the other side. They agreed that it was a most invaluable part of their course;

that the throwing a man on his own resources at a time when his mistakes would not cost him a great deal, as they would in after life, was one of the most valuable parts of his training. It was a test of his capacity, the mistakes in which would not cost life nor money. This they pronounced most valuable training, and they were all strongly in favor of its continuance.

Prof. Lanza was not in favor of doing away with the thesis. It forms one of the most valuable portions of the instruction of the student, as the speaker explained in a paper on graduating theses at the first meeting of this Society.

Prof. Bull wished to ask a question of those gentlemen who held that the thesis was an independent piece of work; he would like to ask them whether, if a student came to consult them on his thesis, he would be answered or not?

Prof. Raymond replied that he would certainly be answered, but the information asked for would not be given him. He would be referred to some source from which he could obtain it for himself. (Laughter.)

Prof. Doolittle remarked that the practice in regard to theses was about as various as in anything else. He knew of one professor who worked with his students in the preparation of their theses, and who was very popular. With his help they did very well.

Prof. Raymond was reminded by the laughter which greeted his remark of the way in which his father was in the habit of referring him to the dictionary when he came to him for that sort of information. He would never look up the question for us, but compelled us to do the work for ourselves.

PROF. ALLEN cited the case of a former teacher who was very much in the habit of doing the same thing; a student came to him one day and asked the meaning of a certain word. The old gentleman answered, "Don't make a dictionary of me!" When recess came, the student went to the dictionary and was saved a great deal of trouble by finding the book open at exactly the right place.

MODIFIED REQUIREMENTS FOR GRADUATION OF STUDENTS WHO HAVE TAKEN FULL LITERARY COLLEGE COURSES.

BY IRA N. HOLLIS,

Professor of Engineering, Harvard University, Cambridge, Mass.

The writer accepts with some hesitation the responsibility of advancing definite views on this subject, since he has had only a few years' experience in teaching. The education of engineers has grown more important from year to year as they have become well recognized professional men, and the papers published by this Society serve an excellent purpose in bringing about an understanding among educators. It is well to have in mind what the colleges are expected to teach, and what equipment the young graduate must have obtained for entrance upon his professional career. In America we pride ourselves upon the judicious combination of theoretical and practical courses given in the technical colleges, and in the scientific branches of universities. How near we have reached the wisest standard, only time and discussion can make plain to us. There seems to be general agreement upon the main principles required in the preparation for the engineering profession, and all teachers realize that a great deal of cramming is unavoidable to complete the education in four years. One great difficulty presents itself in the organization of courses. The student must be expected to obtain at the same time both a fair general education and a technical training. The lawyer, doctor and minister invariably give more time than the engineer, and men going into those professions are content to devote four years to academic education of a general nature, with two or three additional years in special professional work, while engineers can usually spare four years in all. The time, therefore, must be spent on the main principles of the profession, and students should not expect to become specialists until after graduation. While educators fully realize the difficulty of graduating students with the highest equipment, it is hard for the practicing engineer to understand why a young man just out of a technical school does not know practical and commercial matters more thoroughly than a mechanic who has worked all his life at a trade.

There is a certain unjustifiable impatience among the older men who have had no experience in teaching. Engineering is, above all, a profession requiring wide experience. A well-known chief engineer in the navy once complained that recent graduates could not take charge of a watch in the engine room on board ship. He even went so far as to express a preference for graduates from a young ladies' boarding school. Of course, the recent graduate has not had time to learn the practical management of steam machinery. It usually takes from three to five years for a practical man who devotes exclusive attention to oiling and running engines to get a license to take charge of marine machinery and boilers. Yet very few of our graduates in mechanical engineering could not, with ordinary attention, acquire the same practical knowledge in six months. Happily, as university and technical college graduates are reaching the higher positions in engineering, this attitude of antagonism is changing. Engineers now concede the necessity of three or four years of post-graduate work in the office or workshop as a preparation for any specialty. These years may be said to correspond fairly to the professional training in law and medicine.

Students enter our technical colleges with enough mathematics and language to begin the process of cramming, which permits very little time for academic training, such as most of them need. They are usually deficient in their own language, and many of them graduate without being able to write good English, or to express themselves clearly on professional subjects. So far as the literary courses serve to correct this, they are certainly of great advantage. It is troublesome, however, to make a wise selection from the literary subjects, unless students have plenty of time to spare for college work. In the matter of counting literary courses towards the fulfillment of the engineering degree, we are met with a difficulty at the outset. Not all colleges have the same system. Some give a literary course of required work throughout; others make all subjects elective, and still others combine the two systems in different ways.

In the first case a small amount of mathematics and natural science is usually given, and students gain little towards an engineering education beyond acquired habits of study and ability to write English. A four years' course in such a college will seldom enable a student to cut down the required course in engineering by more than one year.

In the second case, where all subjects are elective as, with two exceptions, they are at Harvard, a student may so select his work as to clear off three years of his engineering course while still in the academic department. At Harvard University, and no doubt at other institutions, many of the engineering subjects are regarded as educational, and may therefore be counted towards the degree of A. B. There is no reason why these subjects should not be considered as entirely the equivalent of work done by students registered in the scientific departments. With a careful selection, it is possible for a bright man, by spending four years in the college and one year in the scientific school, to get both the literary and the engineering degrees in five years. The only drawback to this plan seems to be in the lack of practical knowledge with which a student comes to the engineering departments. A certain amount of practical work must be taken, especially for mechanical and electrical engineering, to make plain the courses in designing machinery which are usually placed in the last year. Where the course is entirely elective, the academic student is likely to omit workshop courses which would be required of scientific students in their first and second years. It seems advisable, therefore, to require two years additional in the scientific department after the student has graduated from the academic side.

An ideal course would seem to be three years spent in the academic department of a university, taking workshop and field courses during the summer, followed by two years in the engineering department. This would fit the average man much better than the ordinary four years' course in engineering. The concentrated effort of two or three months in the summer would be much more valuable to a student than work scattered over a period of two years, given once or twice a week.

In the third case, where the academic courses are part elective and part required, the credits would depend largely upon what course the student had taken. All courses in pure mathematics might very well be taken as the equivalent of those given in the engineering department, but the instruction in mechanics for engineers should invariably be given in the engineering department by an instructor who knows something about engineering. The only difficulty in the way of accepting mathematics taught in the academic department is that it may have been given entirely from the theoretical standpoint, with no thought of its use as a tool in a man's profession. This seems to me the great lack in academic teaching for engineers, and yet a very little supplementary practice in calculus will make clear its use in scientific work. The instruction in other academic studies may be accepted without hesitation; in fact, it seems to be preferable to that given in the technical colleges.

There is one decided advantage possessed by students graduated from the academic department of a college. If they enter an engineering college it is usually because they have a taste for engineering. The academic period serves as a period of probation, and a young man has time to consider his tastes and career. He arrives in the professional school older and better able to take the required subjects. One of the chief weaknesses of our technical colleges and departments lies in the youth of its students and their uncertainty about what they really want. Probably very few of the men who begin the study of engineering immediately after leaving the preparatory schools have any real capacity for the subject. Hence it is not always the school or the method which is to be held accountable for the failure of so many students.

These are some disadvantages as well as advantages in academic training for engineers. The chief effort in engineering should lie in the direction of acquired habits of systematic work, and these are not necessarily learned in the literary departments. The student is also likely to find the tendency to books and the library very strong. This may be among the disadvantages, as a successful engineer is essentially a man of action. Good teachers are often produced in this way, but the technical colleges are organized to produce engineers who find their careers in the practice of a profession. The best teachers usually develop, and courses cannot be laid down specially for their education. The value of engineering studies as educational training is overlooked. Business men could frequently deal more intelligently with affairs if they had some understanding of engineering matters, and it seems quite clear that the directors and managers of railroads, steamship lines and mining companies, would profit greatly by instruction in engineering.

In summing up this subject of regulating the admission of graduates from academic departments, the following rule may be suggested: To accept all subjects having no direct bearing upon the profession as the equivalent of the same work given in the technical college; to supplement mathematics with practical examples pertaining to engineering, and to require mechanics and professional subjects to be taken in the technical college or department.

DISCUSSION.

PROF. STORM BULL called attention to a rule at the University of Wisconsin which provides that a person may graduate in six years from the College of Science and College of Engineering; first taking four years in science, and then two years in engineering, on condition that he shall so select his studies as to get all his mathematics required in the engineering course, together with certain similar subjects, at least a year before he graduates from the science course. It is very important that the full amount of mathematics should be insisted upon.

PROF. ALBERT KINGSBURY thought it was the experience of almost all the colleges which teach mechanics and engineering that, after a course of pure mathematics, the student is unable, as a rule, to apply the principles which he has learned in pure mathematics, to the concrete work in mechanics. Taking for instance, the case of determining the centre of gravity; it may be found at the outset that the student is not able to write the differential equation. If this much be done he will get along: but to write this, the vital part of the work, is to him an impossibility. So, too, with the moment of inertia and various things depending on it. It would appear that there is room for a text-book in calculus based upon the needs of the student of mechanics, and containing numerous exercises in writing differential equations, work which the student finds the most difficult of all when he comes to study mechanics.

THE COMPARATIVE VALUE OF GRADUATE STUDY IN ENGINEERING COURSES.

BY WILLIAM H. BURR,
Professor of Civil Engineering, Columbia College, New York City.

In the determination of the value of "Graduate" or any other study in "Engineering Courses" it is essential, in the first place, to define as closely as practicable what is meant by Graduate Study in this discussion, and then ascertain, if possible, its efficiency in serving the purpose for which it is intended. Again the term Graduate Study can have definite application only when used in connection with some well defined curriculum of which it is the most advanced part, or which it is designed to supplement. It will be assumed in what follows that the term is only to be considered in connection with a professional course of civil engineering study, it being further understood that the expression "civil engineering" is to be taken in its historical and true sense, so as to include all engineering not military engineering. This view is taken both because it is essentially the only correct one, and because in no other way can the observations which are to follow be given a sufficient generality. It is clear that a course of study, graduate to an industrial or trade school, even though engineering degrees be given in it, would have a very different meaning or scope from another, graduate to such an advanced professional course of study as a university ought to afford. Hence it is to be clearly understood that in this paper the latter line of graduate study only will be considered.

Having thus outlined in a general, but sufficiently precise, manner what is contemplated under the term graduate study, it will be possible to treat in the fullest detail desired its value or efficiency in the training of the civil engineer for the broadest executive practice or for the practice of any of the specialties. In order to accomplish this end, it will be necessary to consider two classes of study which may be called graduate. One of those classes, and that one which will be considered first, is an integral part of the educational work required for the professional degree, the bachelor's degree being given at the end of a shorter prescribed period of more general and less technical study. Typical of this class of civil engineering study is a three years' course leading to the B. S. degree, and subsequently two additional years of what may properly be called graduate study, leading to the professional degree of C. E., M. E., E. E., or other special degrees, a material portion of which is frequently or usually required to be pursued in connection with practical work. The division of time devoted to this class of courses of engineering study is variable, but the salient features are those typified, viz., a somewhat general mathematical and scientific, or even engineering course of study, preceding a shorter but advanced course of a thoroughly technical character, the attainment of the professional degree being dependent on the successful completion of the latter.

It is probable that two main influences have controlled the formation of such courses of professional study. One of them has arisen from the fact that it has been and is still difficult to secure comparatively advanced preparation for students beginning their courses of study, and from the implicit recognition at least of the desirability of a general or liberal training as a basis for the advanced technical training which should complete the professional man's education, while the other influence has arisen from the belief on the part of some that a professional degree is in some measure an outward assurance that its possessor is, or ought to be, a well qualified practitioner.

It is well to consider whether a defective preparation for the beginning of professional study can be remedied by such means, or whether it is either advisable or beneficial to complete an advanced course of study in such a way. Few instructors in engineering schools will fail to deplore the markedly bad quality of the preparation evinced by a large portion and perhaps the majority of applicants, but is difficult to show the wisdom of any professional school reaching down to supply elementary instruction in its own curriculum, in order to supplement or correct the deficiencies of the preparatory schools whose specific duty it is to afford the best quality of just that sort of training. That kind of instruction has no proper place in the professional school; the best methods of the latter are not adapted to it, and if a real attempt is made to meet the need, that attempt will inevitably result in seriously affecting the efficiency of the advanced instruction by vitiating its proper methods and diverting its efforts from its true aims. The curriculum of the professional school should be jealously guarded against the entrance into it of anything that does not belong to it, even though the application of that salutary principle reduces to some extent the number of students. The things that the preparatory schools ought to supply should be exacted from them; at any rate, if the professional school reaches down with its curriculum far enough to include them, both its prestige and its efficiency certainly will be seriously impaired; it cannot do efficiently that which by its very nature it is not designed to do.

The function of that portion of this class of professional courses of study which precedes the bachelor's degree, as a general or liberal training on which to base the purely technical matter, is open to serious objection of the same general character; indeed, it can be criticised even more forcibly. It is not the province of the professional school to give a general or liberal education; such institutions only attain their highest excellence and produce their best results when their curriculums are established as if the completed general or liberal education preceded them, and when students pursuing them have been subject to the cultivating and disciplinary influences of broad and liberal studies. If the first portion of a professional course of civil engineering study be designed upon some middle or neutral line lying between the liberal and technical fields, with the intent to cover both, it will fail to give the student the full benefit of either, and yield a hybrid result without character in itself and well calculated to defeat effectually the purposes of the graduate portion of the course. The two lines of educational work are quite dissimilar in nature and equally unlike in purpose, and any attempt to combine them or to conduct them concurrently is, from the simple necessities of the case, foredoomed to failure. The general or liberal portion of the professional man's education is of fundamental importance, and it should be conducted and pursued for just what it is, while the technical portion of the work must be performed in its own way and for its own peculiar purposes. No graduate work can correct the evils which flow from the violation of these fundamental principles, for the simple reason that those evils are of such a nature as to prevent that corrective action. The mixture of liberal and technical things will thwart the broad cultivation which the former ought to give, and defeat by necessary superficialities of its environment the purposes of the latter, which are only to be attained by persistent concentration along a comparatively few lines of thought. In other words, when the student reaches the graduate work, he is fitted to pursue it in an incomplete and defective manner only, and the results will be correspondingly vitiated.

These arguments can be materially elaborated and reinforced, but in order to bring this paper within the prescribed limits they have been stated as concisely as possible in their bearing on the main points or salient features of the questions involved. The conclusion, however, is inevitable that the value of graduate study in this class of civil engineering courses cannot be high, either in its own broad field, or in the various specialties of mechanical engineering, electrical engineering and mining engineering, for the reason that that graduate study leading to the professional degree is based upon such unsatisfactory training that it can neither remedy the defects of the latter, nor attain to the highest excellence in its purely technical work.

The second class of graduate study is that which supplements the usual advanced course of civil engineering study, ordinarily extending over a period of four years, and leading to the professional degrees of civil engineering or of the various specialties. This graduate study is not an integral part of the educational work required for the professional degree, but it is pursued in order to attain a high grade of excellence in certain special subjects, and may or may not lead to a post-graduate degree of a philosophical character, and its pursuit may or may not require the performance of work of a practical nature. It should be stated in this connection that the observations upon this class of graduate study are intended to be applicable to those courses of study in civil engineering which are of an advanced professional character, but which lead to the bachelor's degree in science instead of a professional degree, the latter not being conferred even after graduate study.

In all this class of courses of professional study it is, or ought to be, the presumption (as yet seldom realized), that the students pursuing them have taken their general or liberal education prior thereto, so that they are supposably qualified to concentrate their educational efforts wholly on the purely professional work. These conditions, with a few marked exceptions, are at present largely ideal, but the governing principles are as outlined, and they must be so recognized in this paper, even though a considerable period elapse before the results which they surely will secure are realized. Graduate study, then, in this class of cases is no integral part of the professional education, and it is not to be so considered. Hence its value will depend entirely upon the special needs of the particular students who pursue it. If their future lines of work are so well defined that the demands for special excellence in certain subjects or certain branches of technical knowledge are clear, graduate study will be of much value to them. They will be well equipped by their previous educational training to pursue such study to the greatest advantage, and there can be no question about the benefits which they are sure to derive from this class of graduate work. Again, those students who have secured their professional education, and whose circumstances do not require them to support themselves immediately, may wisely pursue graduate study in such directions as their tastes or the probable future demands upon them may indicate. No valid reasons of a general character, however, can be assigned for imposing graduate study upon the advanced professional course in order to secure that educational training which enables a young civil engineer to begin his life work, and which is evidenced by his professional degree or by some degree which is equivalent in evidence to that.

In the consideration of this class of graduate study, no special point has been made regarding the receipt of an advanced degree at the completion of it, for the simple reason that the writer considers such a degree, under the present conditions, as of little or no value or consequence. These studies should be pursued for the benefits which the resulting increase of knowledge confers, and that is ample reward for all the labor incurred. It is not intended in this observation to criticise in an unfriendly manner the practice of conferring advanced or post-graduate degrees really earned, for that practice is based upon a just recognition of genuine excellence in the attainment of knowledge, and is salutary. It is difficult to understand, however, on what basis one familiar with the present general practice of conferring those degrees can entertain much esteem for them as a class. Should the line of graduate study therefore lead to an established post-graduate or advanced degree, it is well enough, and should it not it is equally well, for the main purpose in either case is the gain of knowledge.

Before finally stating the conclusions to which these considerations have led, it is not inappropriate to notice the fact that neither those considerations, nor the consensus of experience, has shown the wisdom of making the course of professional study other than thoroughly technical, and of such length and character as fittingly to lead to the professional degree, but both of these agencies show conclusively that it should be preceded by a broad and liberal training. While there is no inherent prescription of length of that course of professional study, experience has shown that, with the proper preliminary training, a period of four years is well adapted to accomplish the desired purposes, at the end of which the professional degree is appropriately given. Neither reason nor experience shows that a longer period will generally confer advantages commensurate with the extension of time.

It is well to observe just here that the professional degree in any profession whatever does not even imply that its holder is a practitioner, but that he has completed an educational training which enables him so to begin and pursue the practical work of his profession (which is really the practical part of his education) as eventually to attain to the condition of a finished practitioner.

The conclusions to which the preceding considerations lead may be succinctly stated as follows: Graduate study in engineering courses does not possess material value as an integral part of a course of engineering study leading to a professional degree, but it is of essential value as a supplement to such a course of study in certain exceptional instances, where unusual proficiency in special branches of engineering knowledge is required.

Discussion.

Mr. William Kent was of the opinion that the paper probably did not need much discussion, because there would be a general agreement with it as to graduate studies. Graduate studies should be taken by men who expected to devote themselves to one particular line, and thus to especially qualify themselves in that line; but the great body of students should not be required to take post-graduate courses. Furthermore, post-graduate study should not be for any degree, but simply for men who desire to get particular information along particular lines. There were, however, one or two points in the paper to which he would take exception. Prof. Burr spoke of the undesirability of any general culture work in the engineering course, and it appeared that Columbia College, where Prof. Burr is, has no culture studies in its course: but all the other colleges have ten or fifteen per cent. of the whole time given to culture studies, and that seems to be the result of twenty years of experience in a great number of colleges. Another point was the definition of the term "civil engineering." Prof. Burr claimed to use the word in its historical and only correct sense. If that were its only correct sense, then nearly everybody is using it in an incorrect sense. The great body of mechanical engineers surely make a mistake in not calling themselves civil engineers if, according to Prof. Burr's definition, civil engineering is a profession including all engineering not military engineering.

The colleges and universities to-day have different departments of engineering, one turning out civil engineers and another mechanical engineers. They do not tell the mechanical engineer that he is really a civil engineer, and that a mechanical engineer is a particular kind of a civil engineer. As a matter of fact, the profession labels them all "engineers," and the civil engineer has a definite function, the improvement of the earth's surface by the building of bridges, etc. It would be well to discuss this question a little, as to what is meant by the terms "civil engineer" and "mechanical engineer."

THE ECONOMIC ELEMENT IN TECHNICAL EDUCATION.

BY L. S. RANDOLPH,

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The purpose of this paper is to call attention to, and elicit discussion upon, a subject which the writer considers of much importance in technical education.

Attention was called to this question by a report of tests of bar iron, in which the ultimate tensile strength was given to three places of decimals, or thousandths of a pound per square inch, while the probable error was about one hundred pounds per square inch, and the time lost in doing the extra clerical work was about equal to the time ordinarily required to make out such a report.

In following this subject out it will be seen that in many and, in fact, in all cases, the question will arise: "What degree of refinement is necessary?"

In the formula for the breadth of a key given by one of our best authorities on steam-engine details, the decimal .7854 is used. For an assumed size of engine, this gives a breadth of key of 1.225″. If we were to use .8 instead of the long decimal we would get 1.248″. If we were to use .78, we would get the breadth of the key 1.216″. In the actual design of an engine, I venture to say, ninety-nine draughtsmen out of every one hundred would make the dimension 1¼″ or 1.25″. The variation here is less than $\frac{1}{16}$″, which is less than the smallest variation in dimension allowed for ordinary machinery.

This is not a particularly bad case, and a very good argument can be made for its use in that the complete decimal, .7854, is almost as well known as π, and it is important to show that the quantity is not an arbitrary one.

The last two decimals are, however, unquestionably useless for all practical purposes and also seriously militate against the use of the formula for purposes of instruction, as so much of the pupil's time is taken up in useless calculation, which might have been applied to better advantage in seeing that the formula was correctly used.

In many cases the length and complexity of formulæ make them simply ridiculous. It may be argued that these complex formulæ are necessary to explain fully the principles upon which the design of the part is based, but as a matter of fact, they seldom are; the complex formulæ being thrown aside by the designer, in actual practice, and the design of the part determined by other considerations.

May it not also be said that this unnecessary precision is a serious detriment to the pupils' future success? While it is scarcely conceivable that any pupil would attempt to have bar iron rolled to 1.216 of an inch, he might try to have it machined to that diminsion, with disastrous results to his position in his employer's esteem. There are many cases where too great refinement does as much harm as inaccuracy.

The argument which has been urged so frequently against the technical graduate is that his theoretical deductions are not reliable; and frequently this is just, not on account of the inaccurate deductions from the premises, but from the premises not taking into account the commercial or economic side of the question.

The writer, among other methods, uses the following in handling this subject, with the view, first, of impressing on the student that the commercial side of the question must be taken into account, and second, of making him, as far as possible, familiar with its effect on problems.

With formulæ such as the above, attention is called to the limit of error, and when problems are given, as is done quite frequently, the student is asked, after he has reported the result obtained, what size he would make the piece, and what are his reasons for doing so. In some cases he is required, or shown how, to work out and determine the relative economy of the two sizes, taking into account time and material.

In the above case it would be shown that the waste of material would be nothing, as it would have to be purchased of a certain given size and that slightly more time would be required to work to the unaccustomed dimension, and if the keyways were milled out, a new milling cutter would be required to do the work economically.

In all formulæ this method is followed, problems being frequently given where the student is required to assume some of the data. He is then shown the effect of variation in the data assumed.

In machine design this question is constantly brought up. The student is required to make his own designs first, and is then asked how he would chuck them on the machine, how mould them, and in case he has not had sufficient shop practice, alterations in the plan are suggested, and the reasons for them given him. In the opinion of the writer, the best time to impress the effect of the commercial side of the question is during the instruction in designing, for it can be readily shown that a design must not only be good, but that the measure of its worth is its commercial practicability and economy.

In purely theoretical mechanics the subject is carefully avoided.

The greatest difficulty occurs in taking up the subject of the relative economy of different forms of construction, and the principles governing tbe selection of machinery. This subject has been handled so far by means of lectures only, formulating the principles where a statement can be made sufficiently concise, and supplementing it by means of copious illustrations. In some cases the underlying principles can be best brought out by means of one or more illustrations, as for instance: "What kind of boiler shall we use for a given plant?" Boilers can be gotten for from eight and nine dollars per horse power up to twenty-five dollars. It will be at once seen what an enormous effect on the solution of the problem the cost of boiler will have. But the character of the water to be handled must also be taken into account, the price of coal and the work to be done by the boiler. Such a problem as this does not admit of an accurate statement or formula which will cover all cases, but can be handled very satisfactorily by assuming one or two cases and having them completely worked out and the reasons for each step discussed fully.

It is also important that the method of determining the cost of a machine or other piece of work should be studied, and this requires a study of shop accounts and the method of determining and distributing the uncharged expenses or supervision of a factory.

That such work as this should be taken up in our technical courses, many observations such as the one first mentioned, have demonstrated. Recently a graduate in electrical engineering failed to obtain a lucrative position because, when asked to calculate the size of wire necessary to carry the current for a given number of lamps, he reported the results in sixteenths of an inch instead of by wire gauge.

In the writer's own practice, again and again have the young men under him failed to obtain promotion or opportunities for a higher class of work, not so much on account of the lack of knowledge of shop practice as their ignorance of the fact that any other considerations could govern the design of a piece of work than the actual strength; and the experience of others with whom this subject has been discussed has corroborated the writer's ideas.

While to many the introduction of the idea of money and its influence in a course in an educational institution is extremely obnoxious, we must face the fact that the profession of an engineer is, to a certain extent, a commercial one, and that our technical colleges are turning out in large numbers men who will be superintendents, managers, presidents, etc., whose duties will be almost entirely executive, requiring a thorough knowledge of the *economics* of the profession.

DISCUSSION.

MR. WILLIAM KENT regarded this paper as of a little different character from those previously listened to. It was very practical, and dealt with information which the student ought to get in the text-book, but which he did not obtain there; and it occurred to him that this was the result of Mr. Randolph's own experience. The proper way to make a Professor of Engineering was just the way Prof. Randolph took. He had been in active life, in very responsible positions, and had met with the difficulties which he had laid down in this paper. The proper way to make a Professor of Mechanics was to let him graduate from an engineering college, then put him out of it and into practical life for ten years, and then turn him back into the college again.

PROF. JOHN J. FLATHER endorsed the paper very thoroughly. There seemed to be a lack of such educational training of our students in the average technical college. There was hardly a word in that paper that he would not thoroughly endorse. It not only met with his approval, but it very closely followed the practice that he had adopted for the past four years; there were short intervals, now and then, that could be filled in with short lecture courses, as, for instance, one the speaker had in mind during the reading of the paper; there was a lapse of four weeks in the senior year of their course; in that four weeks the students were given lectures in the matter of specifications and estimates of the cost of machinery.

Instruction was given as to the drawing up of specifications and the student was encouraged to become familiar with the contents of such engineering contracts as were available. Regarding the estimates of cost, the speaker stated that no attempt was made to crowd facts into the student, but a few lectures had been given to the Seniors in Mechanical Engineering, in which practical shop methods of ascertaining and keeping cost were discussed and presented to the student, who thus secured well-tried and satisfactory methods that any engineer who had been in the shop realized the need of. The Economic Element in Technical Education should be especially emphasized in the drawing room, since, if this feature be neglected, the student loses much of permanent value to him. The paper was a very valuable one and worthy of careful study.

Prof. J. Galbraith considered that it was not the function of the technical college to turn out finished engineers or to usurp the part played in the education of an engineer by the shop, office and field. The work of the college is to train the student in the sciences and their applications to engineering problems. The teachers should be drawn from the ranks of the profession not because their duty is to give the practical training which can be better acquired in the course of professional practice, but because only such teachers can properly train students in the applications of theory and put them in the position of viewing scientific problems from the engineer's standpoint. The graduate of the technical college ought to be able to read the scientific literature pertaining to his professional work. If he cannot do this, the college has failed in performing its duty and no amount of practical instruction will make up for this failure.

The college ought, of course, to give the student a sufficiently practical training to enable him to enter easily into professional work and perhaps earn enough to pay his board bill, but more than this the speaker regards as a waste of energy. The practicing engineer into whose office or shop the young graduate goes, does not expect from him much either in the way of practical knowledge or judgment. He has a right, however, to expect a trained intelligence, aptitude and flexibility of mind and a fair knowledge of scientific principles.

PROF. ALBERT KINGSBURY said his sympathies were very much excited about the young man who, as had been stated, lost a position by stating the diameter of wire in fractions of an inch instead of by wire gauge. Possibly this did not result from the lack of sufficient teaching. It might have been that he had been carefully and rightly taught not to use the wire gauge.

UNSYMMETRICAL DEVELOPMENT OF ENGINEERING COURSES.

May an Engineering College, with Profit, Allow One Department to Become highly Developed at the Expense of Other Departments?

BY F. R. HUTTON,

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The writer has been requested to take part in the discussion on the general topic of "The Characteristics of the Best Engineering College now Attainable in America," by giving his views upon that branch of the subject which is included under the above title.

It is assumed that it is desired to consider the question of organization of a technical college of some extent and diversity, involving, as that question must, the advisability of giving instruction to students in all specialties of engineering, as well as in fundamental subjects which are common to all.

To give precision to the discussion, let it be assumed that the fundamental subjects before the mind of writer and reader include mathematics, physics, mechanics and chemistry. In an engineering college of the highest grade, each of these subjects is likely to constitute a department by itself, with a professor in chief as head of the department, with whom a number of assistants will coöperate, the number of such assistants varying with the number of students and classes to be instructed. The departmental idea involves the pre-supposition that the head of the department is fitted by capacity and experience for such leadership, and usually the assistants, his juniors, will be men of less weight, although this is not necessarily the case. An ideal department would be a group of men of equal calibre, whose head or chief is chosen either by seniority or other accidental reason, and who stands merely *primus inter pares.*

In most of the engineering schools a number of parallel courses run side by side, each ending in its own appropriate professional degree. A number of men is to be instructed by these fundamental departments, which number is in excess of that which one person in each department can handle efficiently. This difficulty can be met in two ways; and the method of meeting it constitutes the system of organization. The division among instructors may be by *classes,* so that all students of all courses attend a class instructor at one time; or the division may be by *schools* or *courses,* so that students in a certain course, and candidates for a certain degree, are assigned to a special instructor in mechanics or physics or whatever, in the school or course of mechanical, civil or other engineering.

The answer to the question which forms the title of this thesis must, therefore, be conditioned by the principle of organization which keeps the *departmental* idea supreme, or that which keeps the *school* or *course* idea supreme.

I am frank to say that my predilections are in favor of the *school* method of organization, although each system has advantages which are neither few nor small. The pedagogic value of the school organization, its advertising value, and its effect in arousing the enthusiasm of its students and graduates are arguments in its favor. On the other hand, where the salary account must enter as a factor, the presumption is that all students will be better instructed and more stimulated when all come in contact with the head and chief, the specialist of the department. This may not occur in the other organization. The pedagogic value of the school or course organization arises from the fact that architects and engineers may with profit be drilled in distinct classes of problems in applied mathematics, mechanics and chemistry. Mining and electrical engineers do not want the same point of view in their instruction in physics and chemistry, and so the distinction may be made for each course and degree. A further administrative advantage of the school or course organization is that there is usually one person holding the relation of Director of that school or course, and the centralization of responsibility with the coördinating power in one pair of hands mitigates or removes many obstacles which are apt to be present when each department is supreme and its methods a law unto itself.

In so many of the technical colleges of America the organization now prevailing has a basis which is historic and personal, rather than logical and pre-arranged, that it is made impossible to find a general principle which will not compel many exceptions. But in general I would say that, with the departmental idea supreme, it can very easily happen that the development of one department, occurring either at the expense of another or without such effect upon another, would be unprofitable and unwise. The development of a department in a college made up of departments, is likely to be the result of the personality of the individual at its head. Such magnetic personality attracts gifts, the interest of patrons and governing authorities, and secures plums in the way of the best and most commodious accommodations, all of which give rise to evils. While the strength of a whole is made up by the strength of its parts, the strength and growth of departments, which should be logically supreme, should not be repressed or interfered with by an over-growth and development which forces a disproportionate flow of sap into one particular branch. It is difficult to over-develop mathematics and mechanics for engineers: it is easily possible to over-develop analytical chemistry for such students.

Under the *school* organization, these difficulties do not arise, or if they do, their form is different and the evils are more controllable. The development, in any college, of a department which gives instruction in several such schools or courses, becomes now a function of the number of students in each school or course. The number of students for any professional degree is determined partly by the call for workers in that particular field, partly by fashion and partly by the equipment and personnel of the instructors. It has been well pointed out that the industrial development of a country is progressive, and begins with a call, first, for the hunter and trapper; secondly, for the pioneer settler; third, for the mining engineer and agriculturalist: fourth, for the civil engineer and specialist in transportation problems, and lastly, for the engineer who will develop manufacturing. It is presumed that this historical trend explains the development, throughout New England and the Eastern and Middle States, of the colleges and courses in mechanical and electrical engineering. It explains, in part, why one course catches up to, transcends and falls behind another, in spite of the best reputation, equipment and facilities of that other. In the writer's judgment, therefore, the institution as a whole should, for this reason, be organized with a flexibility and adaptibility to the industrial needs of the district and the period, so that in each college the development of the departments which serve it, may be made as the needs of the students require.

This policy of organization, if carried out under a competent and wise executive, would preclude that most regrettable policy of retrenchment which wipes out from an institution an entire course of study because the number of students has fallen below a certain number from no fault of the institution or its officers. This is the worst form of the development of one department at thee xpense of another, because the former happens to be floating at the moment upon the crest of the wave.

The writer does not consider that in this discussion he has by any means exhausted the question of the respective advantages of the two systems of organization. He will be very glad if, by calling attention to this point of view, he shall elicit the opinions of his colleagues, both upon the main question and upon those which are dependent upon it.

THE CIVIL ENGINEER OF THE TWENTIETH CENTURY.

BY ELMER LAWRENCE CORTHELL, D. Sc. C. E.

It should be stated at the outset that this is neither a technical, professional, scientific, nor even an argumentative paper. It is rather an earnest personal appeal to the engineers of the Twentieth Century, who are to take up and go on with the work which we of the Nineteenth Century must so soon lay down forever.

Most of the educators who will read this paper are of the Nineteenth Century; most of those whom they are educating are of the Twentieth Century.

It is fitting for those who have been active in professional work in the last half of the Nineteenth Century to give reflections and advice from their experience to those who, in the freshness of their young vigorous manhood, are soon to enter their Twentieth Century work.

Although we of the Nineteenth Century are not all hoary headed patriarchs tottering on the verge of earthly dissolution, yet we must confess to have seen our best days. Failing sight, stiffness of joints, the bent form, the weariness from work, and many other indications convince even ourselves that we are descending the steep of time and must soon have naught but the tombstone and a decaying memory among living men.

King David in his old age, after forty years of vigorous rule over Israel, was obliged to hand his kingdom over to his son Solomon, to whom he gave advice in the words we now may fitly use in advising those coming after us: "*Be strong and show thyself a man.*"

There are four constituent qualities that, when developed and actively employed, make up a "man," physical, intellectual, moral, spiritual. All are necessary to round out, broaden, deepen, strengthen and develop the strong man. With only one, however, the intellectual, have we now to do, although counseling the most careful study and adoption of the requirements appertaining to the remaining three qualities.

In his recent address before the American Society of Civil Engineers, President Morison sketched for us in clear outlines, and filled in the picture with striking but true colors, the civil engineer of the Twentieth Century; more than that, he surveyed in a masterly manner and attractive style the field of his labors, and set before him a goal for his highest ambitions. That address should be printed in every text-book of civil engineering and be used as an introduction to the engineering course in every engineering college of this broad land, as a sign-board pointing the young man at the outset of his career in the right direction.

With only one of the requirements of a civil engineering education stated in that address are we concerned now.

As a secondary and developing text of our discourse the main features of the fundamental advice of President Morrison's address are here recorded:

"The civil engineer of the new epoch, the epoch which he is bringing into existence by the manufacture of power, must be an educated man; in no profession will this be more necessary.

"The civil engineer of the new epoch must be a specialist. No man can learn to design all the tools by which the powers in nature are to be directed. The work is too great for one man to master. The best results will only be obtained by concentrating effort in a single line. But though the civil engineer must be a specialist, his specialty must not be of a narrow kind; he must have that general knowledge and training which makes the liberally educated man. The real difference between a liberal education and a special education is that one teaches the student to use his mind, and the other gives him information. The civil engineer must have had the mental discipline which qualifies the mind to investigate kindred subjects beyond the limits of his own specialty; his education must be broad enough for this, or he will not be a civil engineer. The knowledge of his specialty will be only part of his education; the mental discipline will be more."

Then speaking of the scope and duty of the American Society of Civil Engineers, he says:

"It will be the duty of our Society to elevate the profession of the civil engineer to the very highest rank among the liberally educated professions." And again:

"Let it now be known distinctly that our profession is one of training and education. The civil engineer is an educated man whose knowledge of the sources of power in nature enables him to direct them for the convenience of man.

"The tools which we have to build are generally large. The physical man is often a tiny thing beside the work which he has to construct. Nothing illustrates the power of mind over matter better than the work of our profession. Though we deal with matter and our work is of a material kind, it is the mind which has made this matter give forth power; it is the mind which is opening the new epoch, and it is by the training of this mind that the civil engineer must prevail. We are the priests of material development, of the work which enables other men to enjoy the fruits of the great sources of power in nature and of the power of mind over matter. We are priests of the new epoch, without superstitions; but if our profession is to do the good work of which it is capable, the true spirit of individual immolation which has characterized the devoted priests of all ages must be found among ourselves. The profession can only do its future work by trained minds working together."

Let us now turn from the lofty and inspiring words of a man of affairs, the peer of any in our profession, and who speaks from a quarter of a century of intense activity on great engineering constructions, to the advice of one of the thorough scholars of the profession, who holds deservedly a high place as an educator, Prof. Wm. H. Burr, of Columbia College. His views were given in a paper properly placed in the lead of a series of well written papers on Engineering Education, bound in the first volume of this Society's proceedings, and read before Division E. of the International Engineering Congress held at Chicago in 1893:

"In the older learned professions this sequence of broad and general cultivation prior to, and forming the foundation of, the subsequent professional training is well defined, and the ultimate nature of the case in engineering is precisely the same as that in law or medicine. By means of a liberal training the requisite powers of observation and a sound judgment are more symmetrically developed and far more accurately applied in consequence of truer conceptions of the object on which they are brought to bear, and a correspondingly enhanced power of healthy mental assimilation is acquired. The broad cultivation, it matters little when or where it is obtained, is the only effectual corrective for that narrow and malformed excellence in some special direction, which, while it is certainly much better than no excellence at all, falls lamentably short of the vigorous and well-rounded product of the ideal education in engineeering. The writer unhesitatingly places, therefore, as the first and fundamental requisite in the ideal education of young engineers, a broad liberal education in philosophy and arts, precedent to the purely professional training."

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"The complete and satisfactory discharge of such functions cannot, from their very nature be accomplished on a bare possession of technical knowledge. This is, indeed, essential, but it is just as essential, and perhaps more so, to know how to use it."

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"There are, then, few professional men to whom the broadly cultivating influences of a liberal education are more needful than to the engineer. His early professional practice does not induce any development which can fill the voids of a faulty general education, while his latter practice demands what only liberal training can supply."

These are the clear and forcibly expressed views of engineers addressed to engineers and for engineers. Let us now speak as *men* to *men*.

I see before me in my imagination an audience, vast and interested, of young men, boys of the age of fourteen to eighteen, who are perhaps at this very moment endeavoring to decide upon their future course, and longing for something to be said to them as the coming men of the Twentieth Century, the future citizens of the Republic, who, while they are to be engineers, are first to be *men*. They are asking what advice we have for them. Do you remember the heralds who stood on the peristyle on Chicago Day at the Great Exposition, and flung out their clarion call to that vast waiting multitude across the Grand Court of Honor? They were ordinary men, so small in the distance as to be hardly recognizable, yet their voice was heard clear and shrill, calling to the duty of the day. We, and this includes others who believe as the writer does, who address this vast imaginary audience, are men lost in the distance, but as representatives of the great body of liberally educated men of the Nineteenth Century, we stand on the peristyle looking out over your heads as you congregate in the Grand Court of Honor of the Twentieth Century, and blow the clarion call to you to score your mark upon the face of your century higher, and wider, and deeper, than we have upon the face of the Nineteenth Century. To each we come with King David's living words: "*Be strong and show thyself a man.*"

A man first, an engineer afterwards. How may you best become "strong?" Testimony to the necessity of a broad liberal education for this strength, and as a foundation for your lives and at the same time for your professional work, will influence you more potently than any argument, and as the writer only desires to accomplish this worthy purpose he will go on quoting from the words of those who, by experience, have a right to speak to you and to whom you are in duty bound to listen and take heed.

One of the educators of the age, not only of large experience with young men at school, but having an intimate knowledge of their later life, character and usefulness, President Timothy Dwight, of Yale College, speaking of this liberal and higher education, says:

"He may not be a philosopher, or a poet, or a statesman, or a scholar; but as educated, and because he is educated, he is thoughtful, rich in his resources for himself and for others. This is what the higher education means, and it has no truest and deepest meaning apart from this. This developed power of serious thought is the essence of educated life. It is the fountain of living water within the mind, which is for every educated man the blessing of such life. To have rich thoughts, serious thoughts; in the sense ot calm, serene, earnest, intelligent, cultured, generous, manly thinking on any and all themes which are worthy of human thought, what blessing for the mind can be greater, or can contain in itself more truly the secret of the best living? Everything good to think about and the cultivated power to think about everything good, for this we are educated with the higher education. Being thus gifted with the education we receive, we overflow and outflow, as it were, because of the life within us, to all whom we see and know. Being full in ourselves, we give fullness to others.

"Education is, first of all, for the sphere within the man and not for the sphere without him. The work for the outward, which is to accomplish its results for the well-being and up-building of the world, is to be the outcome of the energies within.

"Who knows that results are greater when the man understands only one thing and thinks of only one? The results that are seen may, perchance, be greater; though this, as relating to all cases, will need proving. But those that are unseen, who can tell of them? And the unseen results are often, if not always, the greatest and most important. In the unseen region is influence. It is itself, in the largest working and measure of it, the most unseen of all things. But what influence is, and from the nature of influence will ever be, so wide-reaching as that of a rich mind and soul which are filled out by education on every side to their fullness of culture and beauty?

"The worker in the great workshop to which the higher education opens the door may think of and know what is beyond his special sphere, and he must do so for the general good, because in the higher region where he dwells it is not mere *workers*, but *men* whom the world needs for its well-being.

"Such, as we may hope and believe, is the education which the schools in the coming century will bring to those whose privilege it shall be to be trained under their higher influences. The failings and weaknesses of the old systems will be laid aside. The wrong working and false ideas of our time and the time behind us will be put away, and a completeness will be given to that which has hitherto been partial and incomplete. The era will be for the schools, as well as for the household and the individual, an era of wide culture, in which the higher education will be valued for what it gives the man of thinking power and range of mental life. The divine truth will be realized; the man, not for rules, not for uses, not for the mere outgoing of energy towards the world, but for the mind and for thought, to which all these things will render their service, and in which will be blessing alike for the individual and for the race."

These earnest words ought to be written in letters of light, and like a grand piece of pyrotechnics, be displayed before this immense audience of young men, and be thrown upon the darkening twilight of the Nineteenth Century, to light up the grand and beautiful fields of usefulness of the Twentieth Century, upon which you are so soon to enter.

Now let me search for a word from the ranks of the clergy who are training young men for still higher paths than those of earthly manhood. Listen to the views of so great and good a man as Bishop Potter, who recently at the one-hundredth commencement of Union University at Schenectady said:

"The time will never come when a man who has not merely learned certain chemical combinations so that he can manufacture a fertilizer, or certain mathematical combinations so that he can build a railroad, but has also learned what made a little peninsular in the Adriatic the mistress of the world, or how Roman law became the basis of the jurisprudence of Christendom, or how the fall of empires was foreshadowed in the 'Republic' of Plato, or how the growth of a corrupt and privileged ecclesiasticism brought about the transformation of modern Europe, the time will never come, I say, when the man who has learned these things, not a parrot-like learning, but in the length and breadth of their vast and enduring significance, will not be, in every highest sense, the master of him who has not."

Never, indeed, was there an age when the State demanded of its sons, in whatever relation they are to serve it, a larger culture or a riper learning.

One of the great practical educators of the day, Bishop Vincent, founder of Chatauqua and its well-known literary course of study, has regretted all his life that in his boyhood he decided to preach before obtaining a college education; "the more he worked in his profession, the more keenly he felt the value of a thorough mental training. His lack of it became a constant regret." To off-set this lack when it was too late to go to college, he conceived the plan, reaching through the years, by which, in connection with professional duties, he might turn his whole life into a college course, and by force of personal resolve, secure many benefits of college education. Let us use now his own words:

"I remembered that the college aims to promote, through force of personal resolve, the systematic training of all the mental faculties to the habit of concentrated and continuous attention; that the mind, with its varied energies, may be trained, and thus prepared to do its best work, subject to the direction of the will; that it cultivates the powers of oral and written expression; that it encourages fellowships and competitions among students seeking the same end; that it secures the influence of professional specialists, great teachers who know how to inspire and to quicken other minds; and that it gives to a man broad surveys of the fields of learning, discovering relations, indicating the lines of special research for those whose peculiar aptitudes are developed by college discipline, thus giving one a sense of his own littleness in the presence of the vast realm of truth exposed to view, so that he may find out with La Place that 'what we know here is very little; what we are ignorant of is immense.'

"The task before me was to secure these results to as large a degree as possible; mental discipline, in order to intellectual achievement, practice in expression, contact with living students and living teachers, and the broad outlook which the college curriculum guarantees. This aim, therefore, for years controlled my professional and non-professional studies."

Let us now hear what one of the lawyers, president of one of our greatest railroads, and a man of commanding influence, Chauncey M. Depew, has to say.

In his address before the Tenth Convocation of the University of Chicago, April 1, 1895, he gave utterance in the following words to his decided views from out a very rich experience and an intimate knowledge of men:

"It has been my lot in the peculiar position, which I have occupied for over a quarter of a century, of counsel and adviser for a great corporation and its creators, and of the many successful men in business who have surrounded them, to know how men who had been denied in their youth the opportunities for education, feel when they are possessed of fortunes and the world seems at their feet. Then they painfully recognize their limitations; then they know their weakness; then they understand that there are things which money cannot buy, and that there are gratifications and triumphs which no fortune can secure. The one lament of all those men has been: 'Oh, if I had been educated! I would sacrifice all that I have, to attain the opportunities of the college; to be able to sustain not only conversation and discussion with the educated men with whom I come in contact, but competent also to enjoy what I see is a delight to them beyond anything which I know.'"

The college in its four years of discipline, training, teaching and development, makes the boy the man. His Latin and his Greek, his rhetoric and his logic, his science and his philosophy, his mathematics and his history, have little or nothing to do with law or medicine or theology, and still less to do with manufacturing or mining, or storekeeping, or stocks, or grain, or provisions. But they have given to the youth when he has graduated, the command of that superb intelligence with which God has endowed him, by which for the purpose of a living or a fortune, he grasps his profession or his business and speedily overtakes the boy who, abandoning college opportunities, gave his narrow life to the narrowing pursuit of the one thing by which he expected to earn a living. The college-bred man has an equal opportunity for bread and butter, but beyond that, he becomes a citizen of commanding influence and a leader in every community in which he settles. Within his home, however humble it may be and however limited his income to support it, he has among his books and in the grasp and discussion of the questions of the hour, enjoyment which is denied to the man who has not drunk at the fountain of knowledge and the well-spring of inspiration which flows only in the college or the university.

"The best proof of the value of a college education in all the pursuits of life is to be found in the eminent success of those who have enjoyed it, in the higher walks of the professions, of statesmanship, and even of business."

After Morison, Burr, Dwight, Potter, Vincent and Depew, the writer may not venture to say much by referring to his own experience, but all can speak more earnestly from their own experience than from that of others. Therefore the writer wishes to say, and as earnestly as language can convey his meaning, that in twenty-seven years after being engaged in constructing engineering works and in association with engineers from the lowest to the highest, he *knows* that the best equipment, not only for life but for the grand profession of engineering, is a liberal education, such as only the best colleges can give; after that, the special professional course in the higher studies and the special training of our best professional schools.

A few weeks since, a young man who was graduated only three years ago with the degree of Civil Engineer from one of our best colleges lamented that he had not taken the degree of Bachelor of Arts, and later his professional degree by a post-graduate course. He has found himself already handicapped, his mental vision limited, his powers too restricted for the professional work in hand, and still more as a *man*.

The men who become great specialists attain the highest success if they have had the broadest possible training. They then have the more comprehensive grasp and the more complete mastery of the subject.

Mental power is the essential requirement to the greatest usefulness in life, and yet, after all, *character* is the real true ideal of life.

A narrow education and lack of the best mental training weakens character.

We have no right to sacrifice this noble character, possible to us all, this true and harmonious development of the ideal man, for gain of riches or of rank.

In weighing and deciding the important question whether you will take a special course now, or first a liberal one and then a special one, let not the false notion that you will gain time by the former method influence you. From a pretty intimate knowledge of broadly and narrowly educated men, the writer can assure you, that the young man who adopts the course recommended, and takes three, even four years more than you, of study in the schools, will distance you in less than five years if he is of equal natural ability.

Many times in the last twenty-seven years has the writer been supremely happy in the fact that he took the degree of Bachelor of Arts from his Alma Mater, Brown University. He has had with him during all these years, and from the very first plunge into professional work in 1868, an abiding faith in his mental powers and training, to master any problem forced upon him in the line of professional work.

The writer was glad to testify to this training and discipline of his four years course in college, when, last summer, he was invited to speak to the alumni of Brown, there to acknowledge that his right to accept the degree of Doctor of Science, then conferred upon him in recognition of work done in his profession, was the direct outcome of sound mental training that years ago was given him within the walls of that university.

Impressed with the great need of an education for engineers higher than is usually obtained by them, the writer has for many years been very desirous of seeing a great college of engineering established in connection with some one or more of our best universities.

This desire was so strong that he was impelled to write an urgent letter to the projectors of the University of Chicago, about the time of its incorporation and founding, urging the inception at least of a great engineering college, one principal object and work of which should be the education of men for engineers, who have graduated from that University, or from some other college of high rank, in the courses of liberal arts and literature.

Probably either the earnestness of the letter, or the reasonableness of the views, or the approval of the suggestions by the projectors of the Chicago University, led them to select the writer as one of its Trustees, by means of which position he hopes yet to accomplish the great object he has undertaken.

These remarks made largely to the educators will, it is most earnestly hoped, reach through them the young men whom they are training and leading year by year into the rich fields of engineering.

The civil engineer, and in that term are included all engineers except military, and even they, in our country, in this time of peace, are really civil engineers—the Civil Engineer of the Twentieth Century must be equal to the demands upon him as a professional and as a man. In our time, our Nineteenth Century, we have laid the foundations for great achievements in the Twentieth Century.

The locomotive, steamship, telegraph, ocean cable and electric motor have had their birth. The great sources of power in Nature have been usefully directed to man's benefit. Who can predict the developments in the directing of these natural forces in the coming century?

Again the strong and increasing tendency intellectually is towards higher, broader, deeper culture. The Twentieth Century will go far beyond the Nineteenth in this respect. The civil engineer should not only be abreast of the times professionally; he should, inspired with the grandeur and usefulness to man of his profession, aspire to reach the top intellectually, and in manhood and citizenship be equal to any. "Be strong and show thyself a man."

DISCUSSION.

PROF. MANSFIELD MERRIMAN wished to endorse, from one of the results of his own experience, the main idea conveyed to us in this very interesting paper. It was probably the case in all engineering colleges, that students came from other institutions prepared to enter the sophomore year or the junior year by passing off the previous subjects in the course. Some of these students were graduates of other institutions, and thus had completed certain courses of study. It was the speaker's experience that of all such students who had come to the institution with which he was connected, those best prepared were the graduates of classical institutions. By a little hard work they were able to enter at the middle of the course ; they knew how to study, had an earnestness of purpose and a high appreciation of the application of principles of technical education ; and after graduation, as engineers, they took at once a rank in their profession which was certainly very gratifying.

PROF. JOHN B. JOHNSON wished to add his belief in the same views and to draw this distinction : While many probably agreed that at the end of four years in an engineering college, it would be better for the average student to go into practice than to study another year in the college, yet this was a different proposition. In that case he believed that four years are better than five. The student would do better to leave the technical college and get into practical work, than to continue longer studying the theoretical principles of engineering ; but this proposition should not be confused with that advanced in the paper, which was to take six or seven years of scholastic training, ending finally with the engineering course. This was a very different proposition from that which would keep him a longer time on purely technical work.

Prof. Gaetano Lanza said, in regard to college graduates in engineering, drawing from his own experience, that he had in mind some students who had taken the college course first who had done very good work, but he had in mind others of that class who were very poor students. It did not seem that what a few men had accomplished in after life should warrant such sweeping statements as those made by Mr. Corthell. In talking about civil engineers and mechanical engineers, the results of Mr. Corthell seemed to be equally applicable to all engineers, for the moment a man came to be responsible for large problems, it was difficult to assert that he was a civil engineer rather than a mechanical engineer, or a mechanical engineer rather than a civil engineer, and either term really denotes a general engineer.

Mr. William Kent claimed the fact that college graduates became better students than the ordinary man who had not taken a college course might be the result of accident. If Prof. Merriman would look over the ages and characteristics of the college man, he would find, possibly, that the college graduates were generally older than the average student and that they came to the engineering course from a deliberate choice, knowing what they were after. But this condition, perhaps, might just as well be found where young men had not had a college training, but had received a business training. Generally speaking, that engineering student would be to a certain extent the best, who went into the school the latest in life, no matter what his previous training had been. The evidence did not appear strong enough yet to say that the best training for a man was for him to take the A. B. degree first. It was largely because the college man was older and knew better what he was about, that he succeeded well in the engineering course.

Prof. William G. Raymond thought that we also should remember what Professor Marvin said yesterday, that the engineer is a man.

A COURSE OF STUDY IN PHYSICS.

BY CARL L. MEES,

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When requested by your energetic and active secretary to briefly outline a course in Physics for engineering students and discuss the same, the writer somewhat rashly accepted. The difficulty of presenting the subject in a general manner, and not only from the standpoint of the needs of and the adaptability to the institution with which he is connected, did not impress itself upon him until the matter was given some thought. The writer does not know whether he can formulate a course and discuss it so that it may be applicable to the several institutions here represented, each one of which must possess peculiarities to some extent characteristic of it; it would be unfortunate if such were not the case and all were cast into the same mould. Such individualities will depend upon location, environment, endowment, character of teacher and student.

The details of a course of study in any department must adapt themselves to these influencing causes in order to be honestly and successfully carried out. For instance, in an institution drawing its students almost entirely from within the borders of its own State, with a strong influence in shaping the preparatory work, or one having its own preparatory department, the time allotted a subject and the manner of treatment may be entirely different from that required in another institution whose students come from all States and Territories. As this paper is to be confined to the consideration of the work to be done in the engineering college, this difficulty forcibly presents itself.

Physics is taught in every high school and preparatory school in the country, and taught in nearly as many ways as there are schools; the utilization of the fruits of such instruction in a class composed of students representing all these grades and building a course upon them is certainly a vexing question, an almost hopeless task.

It will be assumed then, though it may be a little rash, that upon entrance, students have had some useful instruction in physics represented in amount and character by one of the better American text-books, with a little qualitative laboratory practice.

Having disposed of this difficulty in the discussion, we are confronted at once with the question, "What shall we compass under physics in the engineering college?" Until within a comparatively few years, physics was defined as the study of matter, its properties, relations, and the causes affecting it without change of composition; considered usually under seven distinct heads: properties of matter, phenomena and laws of mass motion, sometimes called mechanics or dynamics; sound; light; heat; magnetism and electricity. In recent years it is defined as an exposition of the phenomena of nature which involve the associated energy, without the rigid divisions into the distinct subjects of the first definition. Taking the latter definition as being more correct, physics becomes essentially a dynamical study in so far as its principles are concerned. In most engineering colleges, dynamics, so called, is taught entirely in the mathematical department; in consequence it is found that the student in engineering as well as in physics, when so taught, is unpracticed in the application of dynamical principles to concrete physical problems; given fundamental equations, he may be able to apply mathematical analysis mechanically, but, like the young essayist, never knows how to begin and for that matter frequently does not understand or even find the end.

I quote from the preface to Thomson and Tait's Natural Philosophy: "Nothing can be more fatal to progress than a too confident reliance on mathematical symbols; for the student is only too apt to take the easier course and consider the formula, and not the fact, as the physical reality."

The writer contends then that dynamics should be taught largely as a portion of physics; be taught by a physicist, who, of course, must be thoroughly capable in mathematics. The subject of kinematics may have to be briefly taken up as introductory to dynamics, though it really belongs to mathematics and should be left there.

Elementary dynamics may well be begun in the Freshman class and substantial progress made, even though the mathematical knowledge of the student be very elementary. The study in physics, including dynamics, being strictly quantitative, the greatest care should be exercised to be accurate in terminology, definitions and the use of units. A careful discussion of units and measures should be taken up in the simplest form. There is comparatively little difficulty in this matter of units and measures, if the instruction from the beginning be rigorous and logical; though from existing confusion it would seem to be one of the most troublesome. As long as we deal with kinetics we should adhere strictly to the kinetic unit and avoid the ambiguous terms weight and weighing. The constant adherence to one system until the student understands the formation of derived units, dimensional equations, and the conversion of the numerical value of a quantity measured in terms of one unit into the numerical value measured in another unit of the same order, and can certainly handle it, is of vital importance. Let it be emphasized here that conversion factors are but coefficients of the numbers expressing quantities; it will be safer, perhaps, never to write them as symbols.

When statics is first taken up the same system is to be used until the principles are thoroughly understood; at this time the gravitation units, as more commonly used, may be taken up and the consideration of the theory of units further elaborated.

The writer believes, however, that it will be better to finally set at rest the old gravitation system where the unit of mass is derived and the force unit fundamental. Upon the whole, it is believed that greater confusion arises from this than taking the force unit in the gravitation system as an independent unit, retaining the ordinary mass unit, and merely converting from one unit system to the other by conversion factors. In this connection the writer would also protest against the perpetuation of the practice of using the same name or form of expression for widely different things. Unfortunately a few such names have been engrafted so deeply that they can probably never be gotten rid of; but there seems to be no reason why others more recently introduced should not be dropped; certainly there is no excuse for adding such, and increasing existing confusion and bad practice. Perhaps this topic has been dwelt upon too long, yet the deplorable liberty which is taken in manufacturing units and defining, or rather attempting to define them, is a serious cause of trouble to teacher and student. The writer regrets to say that engineers are among the most grievous sinners in this respect. The diversity of units employed, looseness of nomenclature, mixing of different systems in one problem or article is most troublesome.

Especially among journal contributors and men long divorced from experimental investigation, we find an almost fiendish ingenuity in inventing absurd measures and hashing all possible units in one mess. It is not expected nor desired to revolutionize the system of units as used by the best engineers. It is not expected to force upon them the safer kinetic system, for the gravitation units are in statics more convenient, but it is to be insisted upon that instruction given our young men should impress them with the necessity of being accurate in nomenclature, the uselessness of indefinite multiplication of units because of fancied convenience, and the perniciousness of using the same name or expression for widely different things.

In the Freshman class the first instruction in physics is to be in sound dynamics. The energy concept should be introduced gradually and not too early; it is rather difficult and a friendship of slow growth is most secure. This course should be accompanied by experimental demonstrations, thus bringing in elementary mechanics; it should be made a physical reality, not a mere mathematical concept. It should be made to include mechanics of fluids in so far as a few elementary propositions are concerned. Not less than about thirty-five hours should be given to the dynamics.

The elementary phenomena of heat, light and electricity may occupy fifteen hours of the total fifty given to physics, including dynamics, in the Freshman year. This work is considered as preparatory largely to the dynamics in the higher classes, and to chemistry.

Dynamics should continue throughout the Sophomore year, when more difficult subjects not touched upon in the Freshman course are to be taken up. Problems of impact, collision, central forces, harmonic motion, should be very thoroughly treated; the rudiments of potential and a fuller discussion of energy may follow. In connection with all these, experimental illustrations are most valuable. Not less than two hours per week for the entire year should be given to the subject. In the Junior year the student has a fair working knowledge of the calculus and is prepared to take up the study of physics and dynamics analytically. Dynamics will, therefore, be continued. It may now, perhaps, be turned over either to the mathematical or engineering department, as there will be no longer danger of looking upon it as a purely mathematical study; for at this time it is proper to take up, parallel with dynamics, that which is more commonly known as physics, that is, molecular physics and ether physics, beginning with a brief discussion of elasticity, viscosity, rigidity, surface conditions, surface tension, capillarity, diffusion, and a brief discussion of the kinetic theory of gases.

These phenomena should be illustrated and the principles discussed, as far as possible, dynamically. All the time, and this applies to the introductory course in dynamics as well, the writer would emphasize the value of the solution of problems by students, to be returned to the professor for examination and not for shelving. The problems should be selected so as to be illustrative of principles and general methods of attack, formulated to be real, as it were, and not purely ideal. It is not difficult to so construct such problems that the student may have an interest in the actual result obtained and not merely in the correct solution. Numerical values and constants may be thus stored in the student's mind almost unconsciously, forming a rich fund of information for future use. There is probably no better means of stimulating accuracy than by making the examples real. We are tempted to overlook numerical errors in a student's work if only his method be correct; or reminding ourselves that in practice an error of this character may be most serious, we may for a time go to the other extreme and weigh such mistakes too heavily.

In grading problems it is proper to consider that if the example set the student is made a mere exercise, he will look upon it as of little consequence (like the practice before the ball game where a "muff" counts for little).

Scarce a recitation should pass without its problem set, to act as a nail to fasten the principle discussed.

The study of the phenomena of sound may be brief; harmonic motion having been thoroughly treated in dynamics the equations, etc., are at once available here; velocity of transmission of waves, reflection, interference, Fourier curves, etc., should be old friends. The consideration of vibration of plates, membranes, rods, fluid columns, will be readily and briefly treated and illustrated. Pitch, intervals, overtones and harmonics, in so far as they may be used in physical measurements and in telephony, will be readily treated of in a few lessons. Doppler's principle and resonance must be more carefully studied; in connection with sound this is most conveniently done as offering the readiest experimental illustrations.

The order in which the remaining subjects are to be considered is of comparatively little importance; as a matter of convenience and logical connection, perhaps, the phenomena and theory of heat can be taken next. Then may come the study of expansion, definition and careful discussion of the relations of temperature and heat, the first law of thermodynamics being made fundamental. The foundation may be here laid for the second law of thermodynamics, to be administered in small repeated doses until the student is saturated and can bear at a later stage a heroic administration. Specific heat and change of state can not be too carefully discussed and rigorously treated.

Conduction and convection may be briefly discussed, the practical application in each case to be given principally in the form of examples.

Radiant energy will thus be led up to, and can best be treated as a whole; linear propagation, reflection, refraction, single and double, polarization, etc., may be treated dynamically; and dispersion, diffraction, interference, phosphorescence and fluorescence are not to be omitted. This treatment may be made to cover both light and heat.

The discussion of mirrors, lenses, and optical instruments in general, may receive geometric treatment as being most convenient and useful in ordinary problems.

Electricity and electrostatics are to be briefly considered, including capacity, condensers, etc., the latter to be more carefully treated, giving attention to magnetism, current electricity and theory of measurements in each. The whole subject, as far as possible, should be treated from the dynamical point of view, as stresses and strains, in media and transmission of energy through them, thus not fixing the attention merely upon the conductors, but duly recognizing the importance of work done upon the medium, and of the return of energy from the medium, under proper conditions. This will naturally lead to the consideration of electric oscillations, etc.

In the electrical engineering course and in problems, the device of treating electrical currents as currents of fluids is admissible just as is geometric treatment in optics.

The writer would not spend a great deal of time on the elaborate description of many special forms of apparatus, unless this be necessary to lay the foundation for the use of results in discussing principles.

The time allotted to this course should be not less than one hundred and fifty hours, divided about as follows: fifteen, properties of matter; ten, sound; fifty, heat; twenty-five, light; fifty, electricity.

Laboratory work in physics should come towards the close of the course, when the principles are understood and all the training in mathematics has become available. The writer would, therefore, put it into the senior year, or certainly not begin it until the latter portion of the junior year. The work in the physical laboratory at this stage is to be quantitative, and after a certain expertness in manipulation has been acquired, investigational. It will have much in common with the engineering laboratory work; it will, therefore, be unnecessary to consider certain subjects in more than one department, if there exists a proper understanding between the departments. The investigation of properties of solids, moduli, etc., will be left to the engineering laboratory.

Certain preliminary discussions upon the art of experimentation should be given in the form of lectures, which may be given in either laboratory. A few of these are believed to be not sufficiently emphasized in many cases. The necessity for honesty in obtaining results is undoubtedly brought to the notice of students; there remains, however, a residuum we may call it, of human nature, generally most pronounced in the enthusiast, giving an unconscious bias towards reading indications alike, if they should be so; of bringing results out, or interpreting them to suit their notions or knowledge of what they should be; this should be impressed upon the student. The necessity of varying the conditions in experimentation, so that the final result can not be inferred before calculation, is important.

Second. The discussion of degrees of precision necessary in each step or part of the experiment to secure equal effects upon the result is often neglected. The unnecessary refinement in one step of an experiment is useless, though so very often made the triumphal point in an investigation. Intelligent recording of results and so arranging them as to enable one having some knowledge of the subject to understand the method and results and to judge of their value, seem almost a lost art ; it should be again practiced.

Methods of computation, approximation, etc., will, of course, be presented. These will constitute lecture subjects introductory to the laboratory practice. The necessity for long blocks of laboratory time need not be dwelt upon. It is assumed that no one would give less than three consecutive hours to this work.

The first exercises will be in simple measurements ; these, however, should be made upon objects such that the results may be used in future experiments. The same trait of human nature appears here which we find elsewhere and should be taken advantage of. A student will walk five miles on some pleasure trip, get over the ground quicker, better, and in more cheerful frame of mind, than if ordered to walk five miles for his health by his physician, and he will still get the exercise. Experiments or measures merely for practice do not stimulate the student. The same thing is to be measured by as many different methods as possible, the results compared, and the peculiarities and merits of different methods discussed. Thus a radius of curvature may be measured by different types of spherometer, optical lever, reflection, etc., until the thing to be measured has been thoroughly worked up. The division of laboratory exercises according to the subjects as usually classified in books seems to be unnecessary. If a thing is to be measured, let it be done in a variety of ways; that we jump from the mechanical to optical, then to electrical methods in the first few lessons, matters not, for the principles have been studied in the class room.

The laboratory equipment of an engineering college should be principally in the direction of measuring instruments; display apparatus for brilliant qualitative lecture demonstrations or amusing laboratory experiments is of secondary importance. Apparatus labelled "The Largest Electrical Machine in the Country," the Most Magnificent Collection of Geissler Tubes," "A Large Air Pump from the Paris Exposition," etc., have no important place in the physical laboratory of an engineering college. It is like one boasting of the possession of a nickel-plated spade and barren flower beds, or of fine Royal Worcester ware on the dining-room sideboard, with little to eat.

The preliminary exercises must necessarily be similar for all students, as they are lessons in the use of tools and in acquiring a certain expertness. Probably not more than one-third of the whole time need be given to this work. An observer skilled in the use of comparator, spherometer, dividing engine, balances, observation by telescope, having some expertness in handling glass, making fibre suspension, etc., will soon acquire skill in the use of any device required in the attack of any special problem.

These preliminary exercises having been completed, there come next problems requiring the planning of the manner of attack, the assembling and adjustment and, if necessary, the construction of apparatus, the difficulty of the problem corresponding to the ability of the section (a section not to consist of more than three students). The putting of each student through a fixed and set series of two or three hundred problems, with apparatus all prepared and adjusted, the method of procedure carefully detailed in printed instructions, does not give the best results in instruction. It seems too much like the procedure of the well known advertisement, "You push the button; we do the rest." The result is too often a roll of foggy pictures. By the setting of problems, usually original, fewer experiments may be recorded in the note-books, many pages of results may have been rejected, but, upon the whole, more good will have been accomplished.

No attempt will be made to detail experiments to be performed, for it is assumed that a physicist is in charge of the work ; but reference will be made to the general plan. In an engineering college the exercises may be so selected as to bear more or less directly upon the future profession of the student, though this is not considered essential.

A trained, honest experimenter will feel more or less at home in any branch of experimental investigation if he understand the problem to be attacked. For students who do not take the more extended electrical laboratory work in connection with electrical engineering, the physical laboratory work may be directed more towards that class of problems and measurements.

For physical laboratory there should be set aside no less than six hours per week during the year.

To recapitulate, then, dynamics is fundamental, and a large part should be taught in the department of physics. Instruction should begin in the Freshman class, 35 dynamics and 15 light, heat and electricity. Sophomore, dynamics 75. Junior, dynamics 75. Physics, molecular and atomic, 150. Senior laboratory, 250.

DISCUSSION.

PROF. J. GALBRAITH believed that the physical laboratory should hold an important place in the education of engineers. In the physical laboratory where the apparatus is small, and where a great deal of useful work can be done in a short time, a student can be trained in all the principles of measurement and in habits of accuracy and precision. He was glad to see that Professor Mees makes instruction in dynamics the basis of his teaching in physics. A great deal of the older physics is of little value educationally or scientifically, on account of the neglect of dynamics.

PROF. MANSFIELD MERRIMAN remarked that this very interesting paper had raised a multitude of questions, to the consideration of which a whole day might easily be devoted. However, the time was so short he could speak of only one point, which he would introduce by telling a story, a true one, of an occurrence which took place, he thought, within 100 or 200 miles of Springfield. The Professor of Physics, shortly after his appointment, came to the Professor of

Civil Engineering and told him that he (the Professor of Physics) had studied at Johns Hopkins, Leipsic and Berlin, and that he was satisfied that teaching students to express pressures in pounds per square inch was all wrong. The Professor of Civil Engineering was slightly astonished and asked how the pressure in a steam boiler should be expressed. The Professor of Physics replied that, undoubtedly, *poundals per square inch* was the only true way! Now it seemed to the speaker that the absolute system is a proper one in an advanced theoretical course, but to arrange the elementary course in the way in which Prof. Mees has done, and then with the very first problem to use gravitation measures, is introducing confusion at the beginning. The true method in education is from the simple to the complex. The gravitation units of force, as used by engineers, are simpler than the kinetic or absolute units, used by physicists, and hence should come first in mechanics.

PROF. MEES wished to ask if the mass units are ever used.

PROF. MERRIMAN said that engineers seldom use the pound as the mass unit.

PROF. MEES asked what is used for the mass unit in examples.

PROF. MERRIMAN replied that engineers do not trouble themselves about mass.

PROF. MEES then inquired as to heaviness, whether mass does not enter into that.

PROF. MERRIMAN replied that mass may enter into it, but it is not necessary to talk about "mass." The engineer deals with stresses or forces and compares these in all cases with the force of gravity.

Prof. Mees referred to the swinging bridge problem, and further remarked that it is generally supposed that our knowledge of gravitational force associated with mass is the most general. In other words, more is known about force as a muscular sense of stress due to the action of gravitational force on matter. He believed that the inertia property of matter is really more generally appreciated than the gravitational effort. In case of a collision with a man on a wheel it is more important to know how heavy he is than how hard he is pulled to the earth.

Prof. Albert Kingsbury spoke in the same direction which Professor Mees had just taken. It did not seem to him that the statement made by Professor Merriman was quite true, that the gravitation question is the simple one to begin with. In the consideration of centrifugal force, for instance, the quantity g enters into the expression of mass, and that quantity, occurring in that place, is the thing which troubled engineers more than any other thing in the whole formula. He remembered reading, in one of the engineering papers, a note from a gentleman asking light on this point. His boy could not see what the "blooming g" had to do with it, and for explanation it was necessary to go back to the really simple primary notions of mass and force which were laid down in most of the text-books in physics. The only way to explain the apparently simple thing is to go back to the apparently complex thing; which is in reality the simple way to explain the matter. It seemed to him that this is the way to begin the study of dynamics.

A COURSE OF STUDY IN MECHANICS.

BY R. S. WOODWARD,

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The problems which most frequently confront the engineer in the practice of his profession depend for their solution on a successful answer to the question, " How may we secure the requisite efficiency at the minimum cost?" But the problem assigned by our Secretary to the writer in this symposium is of a more complex character. The science of mechanics is more than twenty centuries old. It holds a position second only to mathematics amongst the fundamental studies of a course in engineering. It has a voluminous literature, and its applications are coextensive with the material universe. It is a science, moreover, which requires a rather high degree of mental concentration for due appreciation of its principles and applications. To the purely mathematical difficulties which lie in the way of an easy mastery of mechanical ideas, there are added the difficulty encountered in gaining correct concepts of matter and motion, as well as the difficulty of dissipating the metaphysical fog which, by inheritance, surrounds the all-important term force. The solution of my problem, therefore, depends on a successful answer to the question, " How may we secure the maximum efficiency for engineers in the study of formal mechanics during the minimum time of perhaps fifty to one hundred class-room hours available for such study in our undergraduate courses?"

It is unnecessary here to discuss the relative merits of the analytic and synthetic methods of presenting the principles of mechanics. It will hardly be disputed that the shortest route to a sound knowledge of mechanics is by way of the analytic method. Nor is it essential to consider at any length the question of adequate mathematical preparation; for it seems to be generally admitted that an elementary knowledge of the differential and integral calculus is now an indispensable preliminary.

Assuming then that analytical mechanics is the subject of study, and that our students are fairly familiar with their chief instrument of research, the calculus, let us proceed to enumerate the chief divisions of the science and those salient principles on which attention should be concentrated.

For more than a hundred years, or since the publication of the great treatise of Lagrange, the Mécanique Analytique, mechanics has been divided into two departments called statics and dynamics respectively; and these have usually been treated in the order named. This may be called the historical division and order of presentation. More recently a third division, kinematics, or the geometry of pure motion, has been added to the others. Still more recently, following the lead of Thomson and Tait in their great work on Natural Philosophy, there is noticeable a decided tendency to divide mechanics into kinematics and dynamics, the latter term being used to designate the philosophy of forces. In this case dynamics is divided into two parts called statics and kinetics respectively, statics designating the relations of forces which produce relative rest of the masses involved, and kinetics the relations of forces which produce relative motion of masses involved.

In presenting a new and difficult science to students, the historical order of the development of its principles is, in general, the best order to follow. Mechanics seems to afford no exception to this rule. The elementary principles of statics are certainly easier of appreciation than the elementary principles of dynamics, though one must admit that the latter principles are essential to a profound knowledge of the former. Without attaching any permanent importance to it, the following order of treatment of mechanics seems to me at present to be most advantageous, namely: (1), Principles of Statics; (2), Principles of Kinematics; (3), Principles of Kinetics. This, it will be observed, is the order adopted by Rankine in his Applied Mechanics. I have, however, substituted the term kinetics for the term dynamics used by Rankine.*

Supposing this to be the order of division and study of our science, let us consider, first, the subject-matter of Statics. Statics, as is well known, may be approached in various ways. For the purposes of the engineer the writer knows of no better presentation than that given by Rankine in his Applied Mechanics, which he has used chiefly as a text in his limited experience as teacher of prospective engineers. This, however, like all of Rankine's work, needs to be supplemented by a good deal of explanation and elaboration; but the methods and principles employed, when duly understood, seem admirably adapted to the needs of the engineer. The argument proceeds from the familiar Archimedean principle of the lever. Almost everyone has a clear appreciation of this principle as exhibited in the handspike, the crowbar, the steelyards, etc.; and the theory of equilibrium in all its elementary phases follows naturally and easily.

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* Nearly equally advantageous and certainly more logical, is the order adopted by Thomson and Tait in their Natural Philosophy, namely: Kinematics and Dynamics, the latter being divided into Statics and Kinetics. This order seems the one most likely of general adoption in the near future.

It is the business of the successful teacher of a difficult science to direct the attention of his pupils to the fewest facts essential to a working knowledge of the subject. If asked to enumerate these facts for statics the writer would say that they may be reduced to one, namely, to the simple fact that the number of conditions of equilibrium is, in general, six. When the student duly appreciates this fact the analytical machinery of statics is easily supplied and applied. When properly interpreted, also, as in d'Alembert's principle, this fact affords the key to the solution of all dynamical questions. Hence we may regard it as the most important single fact in mechanics, and diligent efforts should be made to get it firmly fixed in the mind. A clear apprehension of this fact is especially important to the engineer, who should be able to take a comprehensive view of mechanical questions, and not limit his thoughts to the effects of coplanar forces.

In the way of applications of the principles of statics it is essential that the student should work out in detail a considerable number of typical examples. Some, if not all, of these should be numerical, since formulas are rarely understood fully until they are put to the test of numbers. Of applications in an elementary course specially useful to the engineers, the writer knows of nothing better than the chapter on "Distributed Forces" in Rankine's Applied Mechanics, provided always that the student can have the aid of adequate explanation. This chapter gives a good presentation of the theory of stress, which lies at the foundation of the theory of elasticity and the theory of fluids.

Passing to the second division of our subject, namely, Kinematics, it is assumed that few words are needed to dispose of it. It appears advantageous, however, in an elementary course, to devote a few days to the study of pure motion, or motion divested of the complications introduced by mass. The ground to be covered in such a course is pretty satisfactorily indicated in Part III. of Rankine's standard work already referred to. The catch words to the principles involved are position, velocity and acceleration. The meanings of these are easily learned, and readily fixed in the mind by a few typical examples.

We come now to a consideration of the third, and by far the most important division of mechanics; that is, Kinetics. Herein we encounter principles much less easily appreciated than those of statics and kinematics. The student must not only withstand the shock which comes with the notion of the conservation of mass and the relativity of position and velocity, but he must in general revise his early impressions of the laws of motion of masses. Our average student, as well the educated public labors under the delusion that Newton deduced his laws of motion, whereas he discovered them in the same sense that he discovered the law of gravitation. The first step then is often the painful one of disillusionment, and the student is apt to feel, as one once remarked to me, a sense of insecurity. But this disillusionment, accompanied often by a brief period of doubt and vexation, is an essential preliminary to clear and correct notions in kinetics.

Having appealed to the student's experience for justification of the fact of conservation of mass, and having brought him to a realization of the fact that he is working by a compound process of induction and deduction, it is preferable to introduce him at once to what may be called the fundamental equation of kinetics, namely:

$$F(t_2 - t_1) = M(v_2 - v_1). \tag{1}$$

This may be said to express a hypothetical relation between a free mass M, a constant force F, the time of action $(t_2 - t_1)$, of F on M, and the resulting rectilinear change in velocity $(v_2 - v_1)$, in M; or briefly, when the units are properly chosen, the product of the force into the time of its action equals the product of the mass into the change of its velocity. If this equation holds true for a constant force, the modified form

$$F = M\frac{v_2 - v_1}{t_2 - t_1} = M\frac{\Delta v}{\Delta t} \quad .$$

leads at once to the conclusion that

$$F = M \qquad \frac{dv}{dt} = M\frac{d^2s}{dt^2} \tag{2}$$

holds for all cases. We thus have the general equation of motion of a free particle M, under the action of a force F (constant or variable), and we come upon a definition of force in terms of mass and acceleration, or in terms of length, mass, and time.

With equation (2) available, we may proceed to discuss various simple cases like that of falling bodies, the simple pendulum, the vibration of springs, etc., whereon observations may be made to test the validity of the hypothesis (1). Thus the student will become convinced of the correctness of the relations (1) and (2), and his security will be easily fortified by the wider inductions which may be drawn from the precise measurements of geodesy and astronomy.

The time and space integrals of equation (2) are

$$M\frac{ds}{dt} = Mv = \int F dt, \tag{3}$$

and

$$\frac{1}{2}M\left(\frac{ds}{dt}\right)^2 = \frac{1}{2}Mv^2 = \int F ds, \tag{4}$$

respectively; and these introduce four new quantities, namely, momentum, impulse, kinetic energy, and work.

At this stage of proceedings the theory of dimensions should be introduced. This theory is due to Joseph Fourier, and was first stated in his *Théorie analytique de la chaleur*, published about seventy-five years ago. It was revived by Maxwell in his Electricity and Magnetism, published in 1873, and now finds a place in all our best books on physics and mechanics. An appreciation and use of this theory are of the greatest value to the student and the investigator. It is based on the truism that every term in an equation should involve the same units affected by the same exponents. According to Maxwell, "A knowledge of the dimensions of units furnishes a test which ought to be applied to equations resulting from any lengthened investigation." But the theory does much more than this for the student. It helps more than any device I am acquainted with, to fix the meanings of the terms force, momentum, kinetic energy, work, power, pressure, etc. In short, it is considered an indispensable adjunct to successful teachings of mechanics, and my students are required to make constant use of it.*

When the concepts attaching to equation (2) have become familiar, through the solution of a variety of problems, the advance to the specification of curvilinear motion of a material particle, or the general

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* To avoid ambiguity as to the meaning of the term dimensions as here used, I prefer, for the use of students, to write a table of dimensions of mechanical quantities after Fourier's plan rather than according to the plan now more commonly followed. Thus I would write as follows:

TABLE OF DIMENSIONS OF UNITS WHICH ENTER INTO MECHANICAL QUANTITIES.

QUANTITY	Unit of length L	Unit of mass M	Unit of time T
Velocity	+1	0	—1
Acceleration	+1	0	—2
Momentum and Impulse	+1	+1	—1
Force	+1	+1	—2
Kinetic Energy and Work	+2	+1	—2
Power	+2	+1	—3

In the current literature of the present time, however, one would say, for example, the dimensions of force are $L^{+1}M^{+1}T^{-2}$.

kinetics of a free or of a constrained particle, is easily made. Of the capital illustrations of this theory, none is more important to the engineer than the case of motion in a circle, or the theory of centrifugal force. Next to this, the elements of planetary motion afford an excellent and interesting application to which a few class-room hours may be devoted. It is not essential, however, to tarry long with these features in the lowlands of kinetics. The student should be led on to the tableland whence, by the aid of d'Alembert's equations, he may get a comprehensive view of the whole territory of mechanics. Generally, I believe, the graduates of our engineering schools have not attained such a view, but that it is attainable and very desirable I am fully convinced. In my experience as a teacher it has been a matter of pleasant surprise to witness the easy grasp of d'Alembert's principle by students, when led up to it by means of appropriate concrete cases. Of these latter, masses connected by light strings, as in Atwood's machine, or masses connected by the convenient fiction of massless strings, are perhaps the best.

Armed with the six equations of d'Alembert the student may advantageously make a resurvey of the fields passed over. He is delighted with the discovery that when the terms specifying acceleration of the masses involved are dropped from those equations, there remain the equations of statics, and he sees thus that statics is only a special case of dynamics. He may re-read Newton's laws, and see clearly that all that the first two of them assert is contained in the six equations of d'Alembert, and that the third law was used to establish those equations. The inductive and deductive parts of the argument on which the science is founded become plainly distinguishable, and the student comes to realize a sense of logical security second only to that afforded by pure mathematics.

To fix the meaning and use of d'Alembert's equations properly in the mind, the solution of several problems is indispensable. For this purpose the writer prefers that a few examples should be worked out in extenso to numerical results, rather than that many be worked for the "answers" simply.* In all such exercises in kinetics pains should be taken to bring out the principle of work and energy and at least to indicate its wide range of applicability. Adequate consideration of the doctrine of energy lies, it is believed, somewhat beyond the province of an elementary course; but students may nevertheless acquire all of the concepts essential to a comprehension of most applications of this doctrine in engineering work.

A question of much importance in a course in mechanics, and a question much discussed in the scientific journals during the past twenty years, is that of units. Should we teach our prospective engineers the use of the absolute, or gravitational system of units, or should we teach both systems? My answer to this question is that both should be taught. Indeed the ability to use both systems and to convert one into the other affords the best test of a knowledge of either. Thus, the engineer should know how to convert inch-pounds or kilogramme-metres into ergs, and horse powers into watts.

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* Diligent effort is frequently needed to suppress the habit acquired in the primary schools, of solving problems for the benefit of the teacher, the only object apparently being to get something which may be labelled "ANS." It is difficult to imagine a more dreary and deadening mode of conducting mathematical studies.

Closely allied to this question is another which has also been the subject of much debate, namely, whether in equation (1) above we should write in the place of M, $\frac{W}{g}$, where W represents the weight of M, and g the acceleration of gravity, at the earth's surface. Such use of $\frac{W}{g}$ has the sanction of custom and has generally been defended by engineers. Without desiring to provoke controversy on this much discussed topic, the writer would state that the best usage and the best philosophy seem to be now clearly in favor of abolishing the time-honored $\frac{W}{g}$ from mechanics. At the same time, since we cannot afford to ignore the history of so useful and splendid a science, it is our duty as teachers to explain the old usage and show how to reconcile it with the more advanced views of of our time.

In conclusion, it seems fitting to add a few words concerning the attitude of teacher and student with respect to our science. Fifty years ago mechanics was regarded by many as a dead science, in the same sense that Greek and Latin were then commonly considered dead languages. There are a few educated people still living, who can see nothing in mechanics but a compendium of logical quibbles couched in the dreary formalism of Euclidean statement. There are more who regard the science as a sort of Sphinx's mill whose product is as dry as mummy dust. In view of these common prejudices, care must be taken to forestall any expectation on the part of the student that he has a "dull grind" in the study of mechanics. Moreover, it is to be remembered that the engineer is a component of society and civilization, as well as the designer of a pile driver and a mud dredge. Hence his humanistic nature must not be permitted to shrivel in the dry light of mechanical philosophy. I know of no better way to meet these difficulties than by the incorporation of the salient facts of the history of mechanics along with the presentation of its formal principles. Thus, for example, the doctrine of the lever should be referred to Archimedes; the laws of falling bodies and the elements of dynamics, to Galileo; the theory of the pendulum and the pendulum clock, to Huygens; the parallelogram of forces, to Varignon; the triangle of forces, to Lami; the comprehensive statement of the laws of motion, the discovery of the law of gravitation, and the invention of the calculus, to Newton; the foundation of analytical mechanics, to Euler and Maclaurin; the first great step toward a unification of processes, to d'Alembert; the perfection of the analytical method, to Lagrange; etc. A brief account of these historical facts helps much to fix the ideas, and at the same time to ward off monotony, which is the bane of routine teaching. Other and higher lessons from the history of mechanics may also, not inappropriately, receive passing notice. The intellectual audacity of Galileo, the elevating candor of Huygens, the profound mental integrity of Newton, the extraordinary analytical capacity of Lagrange, the penetrating insight and lofty enthusiasm of La-place, as well as the discoveries and advances made by these heroes in mechanics, may all be made sources of inspiration in the pursuit of the most arduous of the sciences.

Discussion.

Mr. William Kent said he had been exceedingly gratified to hear this paper and would like to ask if there was any text-book in which these ideas were laid down.

Prof. Woodward replied that unfortunately there was none which seems to meet fully the requirements for engineers. His paper had stated that Rankine's work served fairly well as an outline for statics and kinematics, but he used it very little for kinetics, approaching this more by lectures.

Mr. Kent thought there were two phases as to the purpose of mechanics. In one phase it was a useful tool for the engineer; in another a branch of the fine arts or a branch of metaphysics, a beautiful study which regarded rest as a peculiar kind of motion, and statics as only a particular kind of dynamics. Was it not much better to come right down to common sense and say, "Rest is rest, and has nothing to do with motion?" Similarly with the $\frac{W}{g}$, he wished that writers on mechanics would consider whether mechanics was to be used as a tool for the engineer or as a branch of the fine arts.

Prof. Mendenhall was glad to express himself here in accordance with the conclusion reached by the author of the paper, in reference to the points disputed by Mr. Kent. He had the pleasure of presenting, some years ago, a paper on units, in which he tried to show that this $\frac{W}{g}$ had done more harm than it had done good. He believed that those who were instructors in mechanics and physics, those whose duty it was to try to get into the heads of the pupils clear conceptions, had felt that. He recollected that at that time he quoted from Lodge on this point, who said that his experience with students was that they usually look at an equation, and if they think that g should not be there then they put it in; and if, on reflection, they thought it ought to be there they would be very sure to keep it out. In other words, when we tried to avoid that which was to the speaker the simplest of all factors, mass, and to substitute something which was certainly obscure, he believed it was a mistake. He desired to ask Mr. Kent to enlighten him and state what rest is. It was a simple thing to say that "rest is rest," but he would really be glad to know what rest is.

Mr. Kent replied, "When a body does not change its place in reference to the earth or that which it rests upon."

Prof. Mendenhall was disposed to think that the general conception of the expression $\frac{W}{g}$ was very obscure; he therefore heartily endorsed what Prof. Woodward had to say on that matter. He believed it to be certainly one of the most important points developed in the paper that we should proceed along the lines of absolute simplicity. He did not think it worth while to defend the mathematicians; they are old enough to take care of themselves. He thought they had been slightly slandered and hoped they would not be discouraged by remarks which had been made, in view of their splendid accomplishments.

Prof. Woodward felt that the view Mr. Kent took of the subject was too narrow for this time. Since thirty years ago the great science of electricity has been developed, the dynamo is now in common use, and considerable difficulty would be found working the old ideas of mechanics with the new science of electricity. Moreover, as hinted in his paper, it is our duty not to narrow studies, whether the engineer is to be an electrician or not. It is the teacher's business to give the engineer a knowledge, such that he can understand anything in mechanics that may be useful in his profession, and he believed it to be the experience of good teachers nowadays that the old system of using the $\frac{W}{g}$ is objectionable. He should feel it a great hardship to teach dynamics by the old route. Whereas, if what is known as the absolute system is adopted in introducing the teaching of mass, force, weight, etc., there is comparatively little difficulty, and the students will be able to see what this $\frac{W}{g}$ means.

Prof. Mansfield Merriman said that in the discussion of the paper of Prof. Mees on physics he had put himself on record as in favor of the gravitation units in engineering education. Now, that it had come up again, he would like to ask the question whether there is any possible way, either on this earth or on the sun, or anywhere in the universe, by which the value of M can be obtained without using the g? Are there any methods which an engineer or student can employ to obtain numerical values without using the force of gravity?

Prof. Mendenhall asked how he would measure them without these very standards? In practice. in determining the relations of these units, it is found most convenient to utilize the force of gravitation. but we may use one force at Paris, another at London, or anywhere else; but this would not influence the unit of mass, while it would affect the weight. One standard is made equal to another by making use of the equilibrium of gravity on mass. There are other methods, but the best is the statical method. The kilogramme itself is the mass of matter in that particular thing which has been set aside in Paris, and has been agreed upon by about twenty of the civilized nations of the world to be the unit of mass, not the unit of weight. The United States Office of Weights and Measures has published several bulletins, which, he thought, would give an explanation of this, if the gentleman interested would take the trouble to read them.

PROF. J. GALBRAITH preferred the classification, statics, kinematics, dynamics, to that usually accepted. Statics is not merely degenerate dynamics, dynamics with motion left out; mass is also left out.

In statical problems and statical methods, forces only are concerned, and they are handled with equal care whether balanced or not. Statics has for its analogue kinematics, which is concerned with motions alone. Dynamics includes in addition to the ideas of statics and kinematics the conception of mass. Indeed it might be useful to extend the meaning of the term dynamics and define it as the science of the relations between forces and the consequent motions, irrespective of the special physical connection which may exist in each case. The subdivisions would then be founded on the nature of the physical connection between force and motion. Thus under rigid dynamics, forces, masses and motions would be discussed; under elastic dynamics, forces, coefficients of elasticity and motions, (deformations); under viscous dynamics, forces, fluid frictional coefficients (flow).

He found it very convenient in blackboard work to distinguish between pound as a force and pound as a mass by writing the former *pd.* and the latter *lb.*

Prof. Woodward desired in closing to say that it seemed to him that, as a body, we ought to be progressive, and to teach that kind of mechanics that would be most useful to the engineer. In regard to these difficulties which some one had suggested, in using other forms instead of $\frac{W}{g}$, they do not exist. To go back to the old system which had been advocated by Trautwine, and which he was sorry to see had left lingering impressions here, seemed to him to be going backward. The object was not to recommend any narrow system of mechanics, but the most useful.

A COURSE IN ASTRONOMY FOR ENGINEERING STUDENTS.

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At the present time our engineering colleges tend more and more strongly to technical curricula, which deal with professional subjects to the exclusion of non-professional matters, and the author of the present paper, approving this tendency, purposes to state here his conception of a brief course in spherical and practical astronomy, as a part of the technical training of the future engineer. The purpose of such a course should be:

(*A*) To give the pupil some training in the exact use of instruments of precision. His course in surveying has given the student an introduction to the use of such instruments, but the nature of that work and the circumstances under which it is done preclude the placing of any considerable emphasis upon precision of results. To demand all the accuracy which a transit or level can be made to furnish, is in general, bad surveying practice; but only the man familiar with refined methods of instrumental work is competent to form an intelligent judgment of the manner in which those methods should be modified and their rigor relaxed, in any given case. The course in astronomy therefore comes as a supplement to that in surveying, and the pupil should now be taught:

(*a*) That it is his business in each of his problems to obtain from his instrument all of the precision that it can be made to furnish.

(*b*) He should be taught to obtain this precision with a minimum expenditure of care and time. The instinctive tendency of the student mind to execute every part of a given task with equal painstaking needs to be curbed, and the pupil taught what things require minute care, and what may be and ought to be dealt with in a summary manner.

(*c*) As a subordinate matter, he may be introduced to the use of instruments of a higher grade than those employed in his course in surveying.

(*B*) A second purpose of the course is to train the student in the art of computing. Model forms of record and reduction for his several problems should be placed before him and the advantage of compact and orderly arrangement of all numerical work should be strenuously insisted upon.

(*C*) As the concrete outcome of the above training, the student should acquire the ability to determine latitude, time and azimuth, with such instruments as he will use in the orderly practice of civil engineering. The sextant and engineer's transit furnish quite as good an equipment for the course here contemplated as the elaborate outfit of an observatory. The latter belongs to a more advanced stage of study.

The details of a course of study such as is above suggested depend upon the amount of time which can be assigned it in the curriculum, and as a compromise between conflicting interests we suggest a required course of sixty exercises, to be followed by an elective course, *which the student should have an opportunity to elect*, and for which he should receive credit.

THE REQUIRED COURSE. It is presupposed that the student is familiar, as a matter of common information, with the diurnal and annual motions of the earth and the rising and setting of stars. His technical instruction may begin with a formal definition of the zenith, poles, horizon, equator, meridian, and an explanation of the co-ordinates, altitude, azimuth, declination, hour angle and right ascension, together with the geographical latitude and sidereal time, which should be introduced as concepts strictly analogous to the co-ordinates. An armillary sphere, or some equivalent apparatus, is almost essential to the ready acquisition of a working knowledge of the co-ordinates, and it will usually aid the student if emphasis is placed upon the fact that, while any two co-ordinates suffice to fix the position of a star, they naturally fall into pairs, altitude and azimuth, declination and right ascension, etc., the common element between the co-ordinates constituting a pair, being that they refer to the same fundamental plane. It should be further noted that the latitude and sidereal time constitute the relationship between the different systems of co-ordinates, and it will be advantageous to point out the reasons for employing several different systems.

The astronomical triangle, pole-zenith-star, should next be introduced as a device for transforming co-ordinates from one system to another, and the student's interest will be stimulated if it is pointed out to him that the practical problems with which he is soon to deal, such as the determination of time, latitude, and the direction of the meridian, are, in so far as their theory is concerned, nothing other than cases of the transformation of co-ordinates.

The convenient use of the astronomical triangle for the purposes here indicated, requires a knowledge of the "general spherical triangle," and it will frequently be found that the student's mathematical attainments are in this respect insufficient. In such cases it is often an economy of time to devote an hour to the derivation of the general formulæ of spherical trigonometry by the transformation of rectangular co-ordinates, accompanying the demonstration with the requisite precepts for the application of these formulæ to numerical calculation. The student should apply the astronomical triangle to the derivation of formulæ for passing from each system of co-ordinates to each of the others and should preserve these formulæ for use in the reduction of his observations, rather than resort anew in each case to the triangle.

At this stage of progress the student should devote some little time to the numerical transformation of co-ordinates, both for the purpose of familiarizing himself with the several systems and the mode of passing from one to another, and for instruction in the technique of computing, the arrangement of his work, the checks against the commission of error, the mechanical devices for economy of time and labor, and the use of addition and subtraction logarithms, which are usually neglected in the department of mathematics.

It is a common saying among experienced computers, that the only way to avoid mistakes in numerical work is to have acquired experience through the commission of every possible kind of blunder, and there is perhaps no part of his course in astronomy from which the future engineer will derive more practical advantage than this training under the guidance and criticism of an accomplished computer, such as every professor of practical astronomy should be.

This training in numerical work should be a prominent feature of the whole course in astronomy, and without more than a beginning in such work, the student may pass to a consideration of the different kinds of time in the order: sidereal, apparent solar, mean solar time; and should learn to use the ephemeris in so far as it deals with the concepts he has had occasion to employ. He will learn that the various quantities contained in the ephemeris are all variable with the time, and that their values which he is to use must be interpolated from it for the instant at which the observation in question was made, and that this instant must be expressed in Washington or Greenwich time. This seems an exceedingly elementary matter, but it is the writer's experience that students are frequently perplexed by it, and that a little care is required for its elucidation.

The order in which the student shall take up his practical problems is not a matter of primary importance, but it has been found convenient in practice to assign, first, the determination of time from a single altitude, or series of altitudes of the sun, measured with the sextant, showing the student how to use the instrument, and explaining its chief sources of error without going into their mathematical theory. The reduction of these observations brings the student to a consideration of the fact that the altitude which he has measured cannot immediately be employed with the latitude and declination of the sun for the solution of the astronomical triangle, but must first be transformed from an apparent into a true altitude by correcting for the effects of refraction and parallax.

The theory of the parallax may be briefly given, neglecting the earth's compression, but it will usually be better to give arbitrarily the refraction formula than to attempt its derivation. The student will usually have difficulty in determining which limb of the sun he observed, and his perplexity may be used to emphasize the advantage of observing both the upper and lower limbs. So also he will usually require some stimulus to secure the bestowal of sufficient attention upon the determination of the index correction.

The next step in his progress may be a rapid revision of the theory of the theodolite or engineer's transit, which he encountered but probably did not master, in connection with his course in surveying. This work should include the measurement of angles by repetition, the effect of a reversal of the instrument in eliminating its errors, the method of employing its plate and striding levels, and the mode of eliminating the effect of graduation errors. If an instrument with micrometer microscopes is available, instruction in its use may be given at this point, and the instrument first employed for measuring the zenith distance of a terrestrial mark. It is advantageous to throw the alidade level somewhat out of adjustment, in order to impress upon the student that the reversal of the instrument eliminates all defects of this kind from the measured zenith distance.

Although not strictly germane to a course in astronomy, the subject of trigonometric levelling, with the effect of refraction and the curvature of the earth's surface, may be introduced here with advantage.

In his measurements of zenith distance, the student should be taught to bring the level bubble somewhere near the middle of its scale, but not allowed to spend much time in getting a nice adjustment of it, reading the level, and subsequently applying its indications as a correction to the circle readings. This requires a knowledge of the value of a level division, and the student should be required to determine this value by whatever method his instructor deems most convenient.

Passing on to astronomical uses of the theodolite, the student may determine latitude from circum-meridian altitudes of the sun (Gauss's mode of reduction) and azimuth, from simultaneous readings of the vertical and horizontal circles when the line of sight is directed to the sun, combined with readings of the horizontal circle when the telescope is directed upon a terrestrial mark. This mode of determining azimuth, although very much neglected in the text-books, admits of considerable precision and is excellently adapted to the purposes of the engineer.

Thus far the student's problems have involved only work by daylight, but he should now take up night work and will require some instruction about illuminating the wires of his instrument and in reading verniers, levels, etc., by lamplight. His first problem should be the simultaneous determination of time and latitude from equal altitudes of Polaris and southern stars. This method is very little used in America, but it is the best method of using an engineer's transit for the determination of either time or latitude, and should be taught to engineers. An exposition of the method, with examples of its application, has been given by the author of this paper in Bulletin of the University of Wisconsin, Science Series, Vol. 1, No. 3.

An average student, with a good transit and ordinary watch, may be expected within an hour to determine his latitude within 2″, and the error of his watch within a quarter of a second.

The limits of time above allotted, permit the assignment of only one more problem in our course, the determination of azimuth from observations of a close circumpolar star. The student should be taught that, while it is advantageous to observe at elongation, it is by no means necessary to do so, and that by a proper combination of stars, together with an approximate determination of time, he may frequently avoid the necessity of observing at inconvenient hours without in any way imparing the precision of his results.

In outlining the above required course to be given in sixty exercises or less, no reference has been made to a text-book, and the author knows of no text-book which is altogether satisfactory. In giving at the University of Wisconsin the equivalent of the course above outlined, it has been his practice to prepare cyclostyle copies of lecture notes, covering the ground to be traversed by the class, and including in detail the record and reduction of a set of observations corresponding to each problem assigned the student. A copy of these notes is placed in the hands of each student, and he is expected to familiarize himself with the text contained in them, and to use the numerical parts as models for the record and reduction of his own observations. These observations and their reduction, written up in a note-book and accompanied by the requisite formulæ, are preserved by the student as guides for any future work of the kind which he may have occasion to do. This mode of instruction, however, cannot be regarded as altogether satisfactory, and a suitable text-book would presumably strengthen the course.

It does not fall within the scope of this paper to provide in detail an advanced elective course in astronomy. As our schools are organized, such a course must be arranged to meet the requirements of each individual case, but the material available for such a course in a properly equipped engineering observatory may be indicated as follows:

The Transit Instrument. Determination of time in the meridian. Investigation of the constants of the instruments. Determination of azimuth by mounting the instrument in the vertical of a circumpolar star near elongation.

Clocks and Chronometers. Investigation of rates and temperature coefficients.

The Zenith Telescope. Investigation of constants. Determination of latitude.

The Universal Instrument. Refined determination of azimuth. Latitude from altitudes of stars. Time from transits over the vertical circle of Polaris, Doellen's method.

Transit Instrument in the Prime Vertical. Determination of latitude and declinations of stars.

The prosecution of such a course of study necessarily implies a considerable addition to the student's theoretical knowledge, and concurrently with his instrumental work he should take up in the standard treatises such subjects as precession, nutation, aberration, refraction, the reduction of star places, etc.; but we here approach, if indeed we have not already passed, the bounds which separate engineering study from the domain of the professional astronomer.

The points at which the writer of this paper seeks to place special stress are that a brief course in spherical and practical astronomy is properly a part of the professional training of every engineer in whose work surveying is to occupy an important place, and that this instruction can be advantageously given with no further instrumental equipment than that possessed by every good college of engineering.

A SPECIALIZED COURSE IN GEODETIC ENGINEERING.

BY MANSFIELD MERRIMAN.

Professor of Civil Engineering, Lehigh University, South Bethlehem, Pa.

The proposition to establish a four years' course of study in Geodetic Engineering, or Geodesy, as it should preferably be called, is one that the writer cannot regard with favor. Such a course seems neither necessary nor likely to lead to the best advantage of those who pursue it. There is no branch of technical science that the geodesist may not be called upon to use and hence his elementary training should be broad.

The specilization of engineering education appears to have already been carried too far. In some institutions the students in civil engineering receive little or no instruction in machinery, while those in mechanical engineering graduate without any knowledge of the elementary operations of surveying. It should not be forgotten that a broad foundation furnishes the best basis upon which the specialist may build high, and hence it seems to the writer that a curriculum of studies similar to that of our oldest engineering school most nearly approaches the ideal of a sound elementary engineering education.

Geodesy should be taught in all courses in civil engineering on account of the precise training that it can give to students. It demands mathematical perception of a high order, skill in observation, and accuracy in computation. He who is well trained in these will be likely to succeed in doing good work in any branch of engineering.

About five per cent. of the total time in a four years' course in civil engineering is usually devoted to geodesy and practical astronomy. In this short time a good foundation can be laid for post-graduate studies or for practical work. The entire range of geodetic theory and practice cannot be covered in this course, but it is more important that the portions actually taken, be done with thoroughness than that a wide field should be gone over for the purpose of obtaining general information.

An important feature of the course in geodesy is the theory of errors, including the systematic errors of instruments, accidental errors of observations, and errors in computed results due to imperfections in data. The comparison of observation by means of their probable errors, and the adjustment of observed values by the method of least squares, usually opens the eyes of students to elements of precision which can be appreciated in no other way.

An extensive instrumental equipment is not so important as the intelligent use of common surveying instruments. At our last meeting the question was asked: What is the equipment absolutely necessary for geodetic field work? The answer to this, it seems to me, is that the absolutely necessary equipment is a good long steel tape and a good engineer's transit. By the use of the steel tape base lines may be measured with a probable error of one one-half millionth of their length. By the use of the transit in such a way as to eliminate its constant errors, horizontal angles can be determined with the probable error of one second or less.

In a post-graduate course of study in geodesy it is desirable that field work should also be done, with direction theodolites, in trigonometrical leveling on long lines, in pendulum observations, and in comparison of standard measures.

The work in practical astronomy which usually accompanies or follows the course in geodesy proper has been fully outlined in the paper by Prof. Comstock. The principles advocated above seem also applicable here. Azimuth and latitude work can be carried on with the transit and sextant, and it is also desirable that practice with the zenith telescope should be had by under-graduates, while longitude work is perhaps best left for those who take a post-graduate year.

In all geodetic field work the practice should be conducted with the aim of exemplifying principles rather than special methods. Indeed, in any engineering course the object in view should not be to give a student training in a trade, but to educate him, that is to draw out and develope the powers of his mind. He who has a thorough knowledge of principles, and is conscious of his power to apply them in practice, is in a position to attain success in any specialty of his chosen profession.

Discussion.

(On Astronomy and on Geodetic Engineering.)

Prof. Frank O. Marvin desired to emphasize one point in Prof. Merriman's paper, and that was that students could do good work on low-grade instruments. He spent a month in the field this summer with his students in engineering, doing some topographical work. They were doing some triangulation, and had two instruments, one a Fauth instrument, reading seconds by two micrometers, and the other a common engineer's instrument reading to ten seconds. The closest work on the triangulation, it was found, was done with the latter instrument. The students could not handle the larger instrument so well.

He did not wish it to be understood that he did not advocate the use of fine instruments, but he spoke from an educational standpoint; he wanted the students to see their failure and the reasons for it where they obtained a poorer result with a fine instrument than with the lower grade one. The practice with the better instrument was valuable and worth while, even though the time could not be given to make students expert observers.

Prof. C. Frank Allen, referring to Prof. Merriman's paper, said it seemed to him that nearly every one in this session had been pretty strongly on the side of the general foundation course, as distinct from specialization; while he agreed fully that there must be a complete and sufficient foundation, there was in favor of the special course one side that had not been brought out. If the purpose is not the conveying of information, so much as the disciplining of the mind, it will be easy for all to recognize the fact that there is always some difficulty in determining exactly what studies shall be used for this purpose, and if specialization is done in the right sort of way there is no reason why, in each specialty, studies can not be selected that will admirably and perfectly serve the desired purpose. There is, perhaps, in attempting to avoid specialization, and give only a general foundation, a danger that we shall get a smattering of a great many things, instead of taking up certain special lines and carrying them out perfectly and thoroughly. He presumed he did not differ very much in feeling from those who had taken the other view, but it seemed desirable to present this side of the case, so that there should be no chance to misunderstand each other, while possibly some who were not fully in sympathy with our feelings might be led into the idea that specializing must be wrong. He simply meant that there was an opportunity in this for the most thorough drill for the student who, with such preparation, could in after life turn to other branches of engineering.

A COURSE IN BIOLOGICAL SCIENCES FOR ENGINEERING STUDENTS.

BY C. W. HALL.

Dean of the College of Engineering, Metallurgy, and the Mechanic Arts.
University of Minnesota, Minneapolis.

In the engineering colleges of the United States there are at present three groups of studies:

1. *Preparatory studies:* those which cannot be required for admission, and yet are essential to the professional work which is the specific aim of the course; for example, trigonometry, pattern-making, chemical analysis, etc.

2. *Culture studies:* those which are neither preparatory in the sense stated above, nor professional in that they are essential to an efficient comprehension of the profession to be entered upon by the graduate; for example, economics, history, French.

3. *Professional studies:* those which are essential to an efficient working knowledge of theory and practice in any technical subject; for instance, physics, mechanics, the study of materials.

Noting the present wide range of the technical professions and the apparently narrow range of preparation for any specific line of engineering work, it seems that no hard and fast lines can be drawn between the foregoing groups of studies. Consider the very studies under consideration, the biological: it is greatly to be desired that the chief engineer of a railway system, a city engineer, or the superintendent of a mine, be able to discuss the anatomy and physiology of plants and animals, but the lack of that ability seems in no way to diminish his usefulness to his employers. A chemist, on the other hand, must be familiar with biological problems, since his professional duties bring him in contact with them at every turn. With equal emphasis, it can be said that a knowledge of mineralogy and geology is desirable for a mechanical engineer or the manager of an electrical street railway system; but a mining engineer must understand minerals and be familiar with their habits in order to perform his whole duty with efficiency and economy.

Therefore, invited to present some suggestions on a course in the biological sciences for engineering students, the writer assumes that he is expected to consider them as culture studies.

The question then is not how much of the biological sciences shall a student have who must make living things the subject of his professional labors, but rather how much shall be afforded to and required of him who in his professional duties loves to observe the phenomena of nature as presented by living things about him, examine the physiology of his own body, particularly as it bears on his personal enthusiasm and professional skill, and measure his power of accomplishment as it becomes a varying factor which he must at all times take into account in the prosecution of his professional labors.

When a student of engineering has entered upon his professional studies he has but little time for culture studies. No institution with which I am acquainted can afford to give a young man both culture and professional training, so far as these two terms have any different meaning. Such branches as are neither professional nor preparatory to professional studies, must be regarded as recreative or as incidentally contributing to the engineer's capital in trade through facilitating his intellectual processes towards the solution of engineering problems. As a recreation they will be selected to accord with the tastes or the hours of the student, or more naturally, on account of some personality with which he will come in contact through such selection. It is the *personnel* of a college faculty that marks the institution much more than do the methods employed, the habit of work emphasized, or the intellectual attitude which is instilled into the students through the college as an institution of learning.

Taking the biological branches, botany, physiology, and zoölogy, as a clearly defined group of subjects, the fundamental question is, what results should be expected from their presence in an engineering course of study? Incidentally, the question enters, how much time should be devoted to the group? In an attempt to answer this question, the writer would propose a series of negative propositions, with the reasons in their support somewhat summarily stated.

1. A course in biology should not be a course in systematic botany or zoölogy.

Petal and pistil counting was better than nothing in the days when botany was an art, rather than a science; observing coverts and counting scales is less bloody than shooting birds and stoning snakes. This method was once much in vogue in American educational work, but it is fast disappearing, save as incidental to nature study. The sciences go deeper now and strive to lay hold on fundamentals. Besides, names are difficult to remember, and the disciplinary value of mere memorizing of Latin, or of any other, names is, to say the least, a matter in dispute when the new comer supporting the negative has the tremendous advantage of carrying the sympathies of the students involved in the debate. Even when the systematic work is confined to the fauna and flora of a locality, a difficulty arises, should the engineer be called to another district. Latin names are as useless as the knowledge of the number, position and form of feathers, scales, hair, petals and seed pods. Incidentally, the work of identification and classification should be done, since it gives figures before the mind when other relations than classificatory are under consideration.

2. A course in biology should not be a course in laboratory dissection.

Such a course to be of any disciplinary value is a prolonged one. The mere cutting up of a frog or cat is not a course in laboratory dissection, and the practical result of such an operation considered as a disciplinary exercise is *nil*. The prime object of a course in laboratory dissection, as the writer understands it, is to acquaint the student with the first principles of comparative anatomy.

To become a biologist, the student must *orient* himself in the animal kingdom. He must have a comprehensive knowledge of the relations of his own anatomy to that of those forms nearest to him in the daily activities of life. But engineers can construct machines, build bridges, lay out railroads, generate and control electric currents, and sink mines, with no orienting of that character; they have done it in the past at all events.

Still some information touching the construction of fellow animals and what their habits and instincts will lead them to do, is a most admirable supplement to the merely technical education.

3. A course in biology should not be a course in histology; *i.e.*, "the ultimate optical analysis of structure by the aid of the microscope."

The *technique* of histology is acquired only by exercising great care and expending much time; even then, perhaps not more than one in two attains to that mastery which will, from the standpoint of discipline and working habit, pay the cost of the course in time and money. Having acquired the technique, the study of tissues demands further time, since the structure of a single cell goes but a short way towards the building of a body. The expenditure of time for the sake of acquiring information is altogether too great to be indulged in by a student straining every nerve in putting himself in training for professional competition; and in the matter of discipline the training for professional skill and power can be acquired in lines more closely related to, and on material more nearly like that, with which, as a professional engineer, he will have to work.

4. A course in biology should not be one in embryological investigation.

The development of an animal or plant from its beginning up to the time when it shifts for itself in this rough and tumble world is a subject of absorbing interest. It also absorbs time. An engineering student giving the odd and recreative moments of his course to this subject would get but very little either of discipline or information out of it. At most he could get his tools together and outline the work he would do if he could throw aside his ambition to become an engineer and devote his life to embryology. So, with dissatisfaction sure to result, the details of such a course should be left to others, while the engineer, receiving some few statements and suggestions, is allowed to attend to other lines of intellectual activity.

But, on the other hand, in those engineering schools where it is possible to give a brief course, where a master in biology stands ready to guide the students, work can be done leading the highest type of development of the reasoning powers. Its emphasis should lie along these lines:

1. It should inculcate facts and principles touching the laws of life.

2. The relationships between living things should be explained.

3. The influence of man's biological environment should be made clear.

Four exercises a week, for a single term in lectures, recitations and assigned reading are sufficient to cover the work contemplated in such a course in biology.

Discussion.

Prof. C. C. Brown stated that he had introduced biology as one of the subjects for sanitary engineers, and it seemed to be necessary for this particular line of study, for it was used practically in the study of the classes of animal and plant life found in water supplies and sewage.

Mr. William Kent said that he did not wish to attack this paper at all, but, in regard to the study of botany, as he felt a good deal of interest in educating his boy, he had insisted that he should take botany for the purpose of cultivating the observing powers. He believed that something of biology should be taught in the high schools, before the lad entered the engineering college.

A GENERAL COURSE IN CIVIL ENGINEERING.

What Professional Subjects Should be Included in a Four Years' Course in Civil Engineering, and how Much Time Should be Given to Each, When no Specialized Courses in Civil Engineering are Offered.

BY C. L. CRANDALL.
Professor of Civil Engineering, Cornell University, Ithaca, N. Y.

This is a subject upon which our technical colleges have been at work for many years, with the result that there have been nearly as many solutions as colleges. This has been due in part to the environment, both internal and external, and in part to the idiosyncrasies of those in immediate charge of the work. With the development of technical education, and the elevation of civil engineering to the rank of a profession, the effect of the former should be somewhat diminished, and that of the latter should show itself more in method and emphasis, rather than in the subjects presented.

The discussion of the subject therefore seems timely, not with the hope or desire of securing perfect uniformity, but with the desire of finding out what the present tendencies are, and, if possible, what they should be, in order that each institution, while meeting the present demands made upon it, may the better shape its work for future healthy growth and development.

In order to start this discussion the following schedule of professional subjects is presented. The term "professional," is here assumed to include all the technical work as more fairly representing the character of the course than could be done without many assumptions and explanations, if a more limited meaning were given.

The numbers indicate "count hours" per week for a term lasting one-third of a college year, a "count hour" representing about three hours of actual work. The entrance requirements are supposed to correspond approximately with those of Class A of Professor Marvin's paper of last year upon requirements for admission; *i. e.*, to include among other subjects, mathematics through solid geometry, English, elementary science, and one year of foreign language.

TECHNICAL SUBJECTS.	REQUIRED COURSE.
Freehand drawing and sketching	3
Linear drawing and tinting	3
Pen topography	2
Colored topography	2
Lettering	3
Shopwork, or shop methods	3
Descriptive geometry, and shades, shadows and perspective	12
Land surveying	4
Topographic surveying and mapping	4
City and mine surveying	3
Materials of engineering	3
Mechanics, class-room	19
Mechanics, laboratory	7
Road construction	2
Railroad engineering	11
Structural engineering	10
Foundations, masonry construction and stereotomy	9
Least squares, astronomy, geodesy	10
Steam, hydraulic, electric, and other motors, and pumps	6
Hydraulic engineering	6
Sanitary engineering	6
Engineering jurisprudence	2
Seminary in technical literature	3
Thesis	4
Total	137

The instruction in Lettering should be given early in the course; skill and rapidity can then be acquired in finishing the regular drawings, rather than in practicing lettering by itself.

The Shopwork should acquaint the student with the tools and methods, and with the resources, of the shop, as a future aid in designing, rather than attempt to develop his skill as a workman.

The time given to Descriptive Geometry may appear large, but by using the different angles and giving out plenty of original problems, the subject can be so taught as to be of great value in developing the imagination, and in enabling the student to learn to do his own thinking. About four hours of the time should be spent in the draughting room, working accurately with T-square and triangle upon original problems.

The Mechanics should include the Mechanics of solids, of materials, and of fluids. Graphical statics is included under the second, with extensions to masonry arches, arch ribs, continuous girders, and mechanism. The laboratory should be an auxiliary to the class room, primarily for instruction, not investigation. A portion of the experimental work in hydraulics should preferably be in the field.

The Railroad Engineering should include curves and field problems; earthwork formulas, computations and cost; standard structures; staking out work; track work; signals; economics of location; tunneling in rock and in soft materials; street railroad work. Application to the location of several miles of line away from the college campus should be given, with full data as to estimates and cost, map and profile, and dimensioned sketches of structures.

The Structural Engineering should include the analytical determination of stresses in well designed bridges, roofs and frames; also in those with redundant and deficient members, loads applied at other than panel points, etc., for non-continuous trusses. Also the complete design, with details, of a roof truss and of a plate girder or simple bridge, some of the work to be in timber and some in metal.

Under the head of Foundations, Masonry Construction and Stereotomy, there should be discussed the supporting power of soils, ordinary foundations, and those for tall buildings, bridge piers, harbor construction, etc.; construction and durability of different kinds of masonry, with laboratory work in mixing cement and in testing cement and building stones; two or three simple problems in stereotomy, with the dimensions of the templets checked by numerical computations, *e. g.*, platband arch, intersection of tunnel arch linings, wing walls with battered faces, etc.; the complete design of a right arch, including abutments, foundations and approaches, with graphical analysis of stability; design of an oblique helicoidal arch with numerical computation for dimensions, and the cutting of one of the face stones to scale from plaster. The design of the false works for one of these arches should also be included.

The Least Squares should include the development of the formulas, with applications to problems in astronomy, geodesy and other branches of engineering work, including physical measurements.

The Astronomy should include the determination of time, latitude and azimuth, with numerous problems and actual observing. This work presupposes a little knowledge of descriptive astronomy which may be given in a few brief lectures or required for entrance. The Geodesy should include the construction, elimination or determination of errors, and use of instruments; methods of field work; figure of the earth, with resulting formulas and methods of computation; reduction of geodetic and astronomic data; field work under as nearly as possible practical conditions, with computations and maps of results; laboratory work with instruments and with measures for length.

The Steam and other Motors should be taken up from the civil engineer's standpoint, *i. e.*, a thorough understanding of the principles involved and of the results which can be obtained in practice, including efficiency tests, with enough of mechanical detail to show the application of the principles and the difference between good and bad construction.

Under Hydraulic Engineering there should be included rainfall and evaporation, drainage areas, flow of streams, size and construction of storage reservoirs, water supply and distribution, river and harbor improvements, canal construction, interior navigation, economic problems of transportation.

The Sanitary and Municipal Engineering should include house sanitation, sewerage and sewage disposal, purification of water supply, garbage collection and disposal, street surfaces, municipal control of public works, quarantine, etc.

Engineering Jurisprudence should include the underlying principles of law as applied to boundary lines, riparian rights, contracts, public health, and with decisions enough to show the applications in practice and some of the finer distinctions.

The Seminary in technical literature should be mainly devoted to the discussion of topics prepared by the students.

The Thesis may contain the results of investigations, or of experimental work in the laboratory or elsewhere; it may be a project or design, or a review of an engineering work; or it may be largely historical, or descriptive if the material is well digested. The student may receive suggestions and criticisms, but the result should be an expression of his own ability to cope with an engineering problem.

It is difficult to bring out the scope of a course of instruction in a brief statement like the above, for the same name brings up a different impression with each person as to limitation of subject and method of treatment, if not of subject-matter itself.

The object of the course as outlined is to supplement the high-school training by about a year of general work in mathematics, languages, and the sciences most nearly allied to engineering, and to devote the other three years to what has been called professional work. Many subjects along the border line of civil engineering are not mentioned in this list. The underlying principles, and familiarity with some of the more general features of them, should be secured in the chemistry, physics, geology, mechanics, etc., of the course, while the practical results which can be obtained, in many of the others, would be brought out with due regard to limitations and cost, in the problems and discussions in connection with allied work. Moreover, if, in the struggle for education, the student has learned to think, plan and act for himself, he will be able to extend his grasp to the border fields as necessity may require, in the same way that he will have to attack and solve the many difficult problems, some of them new ones, continually arising in the fields with which he has most intimate contact.

The increasing number of men who complete a college course first, and then complete a course in civil engineering in from two to three years afterwards, and the increasing demand for men more thoroughly prepared, leads to the belief that the year of general work will be gradually replaced by professional work in some, at least, of the engineering colleges.

DISCUSSION.

THE PRESIDENT remarked that he was impressed with the fact that it was easier to lay out a course of study than to find time to put it all into effect.

A COURSE IN SANITARY ENGINEERING.

BY CHAS. C. BROWN.

City Engineer, Indianapolis, Ind.

The strict subject of this paper as presented to me by the Secretary is a course of four years in Sanitary Engineering. It is presumed that the intention is to have a statement of the special work considered necessary for the sanitary engineer and a statement of the work usually comprised in a civil engineering course, which must be included in the course in sanitary engineering.

The writer wishes to have it clearly understood at the beginning that the arrangement of a four-year course with the necessary omissions from the usual course is, in his opinion, not the proper method of procedure.

The education of the engineer is not now, nor has it ever been, on a par with the education of men for any other profession. The profession has suffered, as a consequence, from too many men of ill-balanced development, and will never take its proper place unless the preliminary training of the student is broadened and deepened.

The studies of an engineering course, which is as complete as a college course can well be, may be divided into three general classes, between which the lines of division are not always clearly defined. The first of these includes those studies which are intended to develop the powers of the mind in general, and lay a broad and deep foundation for the future work. Engineering courses are deficient in this class. The second has a similar object, but confines the training to more strictly technical lines. The ordinary course in engineering is well supplied with studies of this class. The third is intended to give the student special training and practice in the application of his recently acquired tools to the investigation of problems in the special field of work which he has chosen. The most successful engineer in these days is the one with such a specialty, whose training has been broad enough for him to be able to see all sides of the special work and its relations to other fields.

It will be seen from the above that the writer is contending for both a broader foundation and for special courses, both being necessary to place engineering education on the plane it should occupy. It is evident that the four years of the ordinary course are not sufficient for the program suggested. The following suggestions are offered as to the minimum work and necessary time in the special case of sanitary engineering. A higher ideal, towards which this is but the first step, should be kept always in view.

The term sanitary engineering covers those operations of the engineer which tend to improve the sanitary condition of cities and country. It therefore includes drainage, sewerage, water supply and paving as essential branches, with perhaps some others of less importance.

Under Drainage comes the carrying-off of water from places where it is not wanted, in such manner as to improve the condition of the surrounding country; the permanent flooding of areas of ground and the protection of other areas, from periodic overflow and damage.

This includes ditching, tile draining, storm water sewerage, permanent flooding, leveeing, bank protection, river regulation in general, and related subjects.

Under Sewerage comes the removal of objectionable water and waste from populated districts, as well as the proper disposal of the same, including purificaton if necessary. Plumbing and house drainage are essential parts of this subject.

Under Water Supply comes the furnishing of pure water, and this includes the selection of source, purification of water if necessary, construction and maintenance of works.

Under Paving come methods of treatment of the surface of thoroughfares, disposal of street water, selection of proper material for pavement in each special case, construction of pavement, repair, maintenance and renewal, and in many cities the cleaning of the same. Ordinary road building, while not strictly sanitary engineering, is so nearly allied to street building that it is included. Bridge work and railroad work, so far as applicable to street railways, and railroad problems in cities should also be included as well as garbage disposal from its relation to disposal of street sweepings.

Heating and ventilation of buildings is a branch of sanitary science which should perhaps belong to architecture, as possibly should plumbing and house drainage also, but it is not generally claimed by architects, and as it is largely common to both architects and sanitary engineers it should be included in a complete course in sanitary engineering.

It will be seen that the subjects of study necessary to cover this ground include hydraulics in all its branches, chemistry, biology, electricity, strength of materials and structures, and design of the special structures referred to, in addition to the special subjects mentioned, and in addition to the usual fundamental studies of all scientific and engineering courses.

The amount of time to be spent on the sanitary subjects depends so largely on the previous preparation of the student and the policy of the particular institution as to specialization that it is impossible to give more than a general statement of the relative importance of the subjects. The writer wishes to emphasize the statement that for the colleges with which he is acquainted he would much prefer to have a student take about three and one-third to three and one-half years of the regular scientific training of a general engineering course, with the addition of more "general culture" work, and then spend about one to one and one-third years on the special work of the sanitary engineer, with a minor subject in the general line. The time can be more conveniently arranged in many cases if the course is a continuous one, and the student elects his specialty early in the course and chooses his work at the times and in the amounts to make the best combination.

The claim that a general course is the best because a young man never knows what branch of engineering he is likely to engage in is becoming out of date in this day of specialization; hence the writer believes in such special courses, added to that groundwork of culture. which every college man should have, whether in a classical. scientific or technical line of work.

It is evident that the most important branch of study is hydraulics and its application to practical work in the various branches, and when theoretical hydraulics, water supply, sewerage and drainage are included, they will take nearly half of the time set apart for the special course. The chemistry and biology desirable, with laboratory work, will take less than one third, and the remaining portion will be sufficient for paving, plumbing, heating and ventilation.

The first three to three and one-half years of a college course should be designed principally to give the student the ability to think, to use his tools; the last year or so may then be used in teaching him to apply his tools to the special work he proposes to do in life. The writer finds it impossible to do both these things in a four years' course in the ordinary college, with students of the usual training at entrance, and believes that it cannot be properly done in any college with which he is acquainted in less than four and one-half years, while in many cases five years should be spent. Better yet would be the result if about two years were spent in the training of the mind to know its powers, before any material amount of special work of any sort was entered upon, and then three years of the general technical training and special work, accompanied by a minor study of the "general culture" class.

If the entire time is spent on sanitary work, and it is made a supplement to a general course in civil engineering, an excellent result can be obtained in one year of work. If the work is carried through the regular four years' course, nearly or quite a year of time must be found for it, and this must be at the expense of the general culture work, languages and such branches of engineering study as seem to have no direct connection with sanitary work. When the sanitary engineer becomes a city engineer, however, he must be able to cover the whole field of engineering, and subjects as remote from sanitary engineering as geodesy, astronomy, bridge work, are essential to a full grasp of the duties of his office, and the groundwork in them which the general engineering course offers should not be lacking.

DISCUSSION.

PROF. J. GALBRAITH did not think that the tendency to specializing observable more or less in the curricula of technical colleges was to be commended. It was due, he thought, to some extent to a confusion of ideas.

Success in life in the case of a professional man depends generally on his becoming a specialist; therefore (it is argued) his technical training ought to be special. It appears to the speaker that this conclusion is incorrect. The proper inference ought to be—therefore his technical training should be general. It is only a good general scientific training which will give a man the best chance to seize the opportunity of becoming a successful specialist. The number of unsuccessful specialists is legion.

PROF. BROWN was glad to see that Prof. Galbraith agreed with his position, although he did not think that the writer agreed with his own. It seemed to him necessary to have the general training, but the best engineer, nowadays, was the man who put himself to work on a special line, with a proper relation, of course, to all matters of engineering; but he would make the best success in some one branch. The general training must be had to start with.

PROF. FRANK O. MARVIN felt glad that Prof. Brown put the general training for the student before the special work, especially in this particular line. It seemed to him that when a man went into city work and came in contact with men of all kinds he needed this general training more than in any other line of engineering. The railroad man had to deal with a comparatively small number of people, and so with many engineers in other lines, but the city engineer, from the very nature of his work, was thrown into daily contact with various classes, and if he was to maintain the dignity of his professional life he must have a broad general training.

PROF. DWIGHT PORTER said he was not so fortunate as to hear the early part of this paper, so that he had only the printed abstract as a guide. In looking this over he found some points upon which he desired to speak. In the first place, the scope of the sanitary engineer, as outlined there, seemed to him to be too broadly stated. It was not of the greatest consequence just how such subjects were grouped, but to include such as ditching, bank protection and river regulation, seemed to be rather straining matters. They were desirable enough for sanitary students, but perhaps not more so than for the general civil engineering students. Coming to house drainage, he believed it wise to include that for the sanitary engineer, not because the young graduate was very likely to be engaged in designing that sort of work, but because he must come in contact with it, and because it had a very close relationship with sewerage. Again it seemed natural to include paving in highway engineering rather than in sanitary engineering. Chemistry and biology were referred to by Prof. Brown as important subjects, but this reference was general only. It seemed to the speaker that it was desirable to have some definite notion of what use to make of these subjects, when they were introduced; and that the object should be to give the student a very moderate amount of general instruction in them, and to have in mind to make of him not a biologist nor a chemist, but a person who will be able to understand the work of such men when he comes in contact with it in his practice, so that he can appreciate what is being found out in new methods of disposal, water purification, etc. He agreed that practice to a moderate extent is important for the student in sanitary engineering. The other points mentioned in the abstract of this paper, regarding specialization, etc., are matters of general policy, not peculiar to sanitary engineering, and he would not touch upon them any more than to assert his own belief that four years of technical study are enough for most students, and should be exceeded only in special cases; he also expressed his belief that excessive specialization is not desirable. Civil engineering in itself is a special thing. It is simply a question of how far specialization is to be carried, and he thought there was danger of carrying it too far. One other matter had seemed to him desirable to introduce, which did not appear in the paper under discussion, and that was instruction in hydraulic machinery. It is not practicable to give the student much mechanical engineering, but he will have to deal more or less with such matters, and it is desirable to give a moderate amount of instruction in that line.

A COURSE IN MECHANICAL ENGINEERING, SUBJECTS TO BE TREATED AND TIME GIVEN TO EACH.

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In discussing the subjects to be treated and the time given to each in a course in mechanical engineering, the particular view taken by any one in charge of such a course is naturally the result of his own experience, depending greatly upon the methods used at the institution at which the responsible head of a course received his education. The general bent is given to the instruction by the practical experience or the specialty of the man or men finally responsible for such a course.

For instance, a man who has not become a teacher immediately upon graduating, goes into a class of work in which, from the nature of the business, drawing is of secondary or of less importance. Later he becomes a teacher, and as he does not want to turn out draughtsmen, the amount of drawing is limited and the kind is of comparatively little importance. Another has secured his practical apprenticeship, if you choose to call it so, in machine tool works where drawing is very important, but where there was no use for a knowledge of heat outside the engine-room, and on his becoming a teacher, drawing is all important and thermodynamics of little use.

These men are both right in a way, but on the negative side rather than on the positive. That is, in the first case, drawing is not so important, and in the second case, thermodynamics is not so important if in both cases the teacher is a teacher. *The first consideration,* therefore, in determining the subjects to be taught, and consequently the amount of time to give to each subject, *is the personality of the responsible head of such a course.* If he is of a strongly mathematical bent, the course will be largely mathematical. If he is of the so-called practical sort, the mathematics will be of secondary consideration. This is equally true if the mechanical course is in control of a body of men rather than a single one. as the tendency will be toward the subjects taught by the strongest men in the faculty.

Any division of subjects which does not take into account this consideration will be unsatisfactory in its results. It is, therefore, undesirable that any attempt should be made to do more than make general divisions of mechanical engineering studies, and this will be taken up later.

It has been possible to obtain a fairly accurate record of the work being done by nearly six hundred mechanical engineering graduates of technical schools. with the following result, dividing them into broad general classes. The graduates are from what are known as mechanical engineering courses. and are of ten years' standing or less.

Electrical work	79
Teachers	65
Draughtsmen in all lines,	51
Gas	36
Iron and Steel Works	34
Railways	29
Consulting Engineers	27
Scattering, and where less than 20 are employed,	257
No connection with Engineering	9
Total	587

None of these are graduates of the University of Pennsylvania, but all are from Eastern colleges.

A little study of this table may give us some inkling as to the work which should be done in colleges of mechanical engineering if it is granted that it is desirable to prepare men for their life work in these lines. The large proportion of men who are in the smaller industries seems to point toward the necessity of engineering education, rather than the necessity of engineering training, to make successful engineers. This distinction is used because it has already been made before the society, and it is desirable to emphasize the belief that it is the former, education in contradistinction to training, which belongs to the province of the engineering colleges.

Of the three hundred and twenty-one engineers in the seven classes given above, a little thought will satisfy us that of the thirty-six men engaged in gas making and gas using, but few could have had much training in their specialty, and the same holds true of several of the other subdivisions of the list. It seems then that as a second basis for dividing the work in colleges of mechanical engineering, certain broad subdivisions of engineering education should be made, and a thorough foundation laid in these subdivisions, and our several specialties only called upon to furnish concrete examples of the method of applying these fundamentals to one branch of the profession.

The teacher here has the opportunity of dwelling strongly on his own specialty, but with the limitation put upon him by the man who knows nothing about this line of work, that it is really not so very important from an educational standpoint as the specialist is inclined to believe.

A third matter which deserves consideration is the amount of preparation our students possess when they come to us. This will be a varying quantity for different engineering colleges, but if it reaches a maximum limit, which is stated later, there should be little difficulty in thoroughly presenting engineering subjects. Here again the methods of doing the work is of as much, if not of more importance than the subject-matter. It is upon the amount of regular drill continually kept up during the preparatory years that a successful engineering course can be maintained. It is believed that a knowledge of mathematics and physics sufficient to put a student in proper shape for taking up with advantage a good mechanical course can be obtained in the public schools throughout the greater part of this country. A student should not be admitted to a course in engineering if he simply has sufficient preparation in mathematics and physics; his education should be a broad and thorough one, up to and including the necessary preparation, before he begins engineering work. An applicant for an engineering course should be as well educated on entering college as the successful applicants for any other college course are required to be.

It is the intention to do more than refer to the work which is done outside the engineering department in an engineering course, although this may be outside the intended scope of this paper. All the work done in such a course should be for the sole purpose of benefitting the student, making him a better man first, and then a better engineer. The work should be handled in such a way that it *is* done and the teacher knows it to be so.

First, as to instruction in Mathematics. This is, of course, one of the two foundation stones on which the entire course is built. It is possible to require and to obtain of intending students a good knowledge of all of geometry, of algebra through quadratics, and mensuration through plane trigonometry. The examinations in these subjects should be searching and of the requirements should be rigorously lived up to. Granted that this amount of preparation can be obtained, the amount of time spent in college on pure mathematics may well be limited to ten hours a week for one year. This should mean practically one sixth of the entire time spent in study. The method of doing the work is, for the best results, simply continuous drill. An attempt to teach mathematics to large classes by young men who have had no training beyond that of a college course will never be satisfactory to engineering students. Classes should be divided into small sections and drilled every day. It is not believed that this work can best be done under an engineering professor, but a department of mathematics which fails to ascertain the exact needs of the engineering departments with which it is associated will fall far short of accomplishing its best results. Mathematics is decidedly the right hand of the engineer, whether he forgets his calculus the day he graduates or not. It is that which enables him to do the largest amount of drudgery in the shortest possible time. The contents of text-books are not the valuable things, but the mathematical common sense which so many of us are deficient in, is what should be gotten out of this course. This, with good teachers, not beginners, and in small sections, say not over fifteen, can be obtained in the time indicated.

As to the instruction in Physics, it should be possible to obtain in the public schools an elementary course in physics. Not only would this be of value, for engineering students, but every well informed boy should have this knowledge. Surely if we can call mathematics the right hand of the engineering students, physics will take the next place, and the course in college should be as full as possible. The amount of time which should be given to it depends again largely on the teachers and their methods. If generalities are omitted from the course as far as possible and mathematical physics substituted, in many cases the students will be better for it. Exact knowledge is what is required, and not that smattering of a subject which goes by the name of "general information." The general information should be given by an occasional lecture, the exact knowledge should be obtained by day-to-day drill, again in small classes, by an intelligent teacher who knows what the student is required to do with his knowledge.

The question of laboratory work here comes up. Is it desirable to give the student laboratory work in physics? To a certain extent only, for an engineering student. The giving of a student a piece of apparatus and telling him to do with it a certain piece of work would be of value as preparatory to engineering experiments later, if it teaches him the handling of apparatus and the faculty of recording exactly what he sees. Beyond this, there is a large amount of time which can be better spent, unless the instruction covers many of the experiments usually carried on in the general mechanical laboratory. The principles of the measuring apparatus, and the apparatus itself, which an engineer is called on to use, would give a student the proper kind of work for a physical laboratory. The standardizing and using of instruments such as thermometers, gauges, indicators, planimeters, resistance boxes, etc., could well be handled in the physical laboratory to the decided advantage of the course. If this is done, the class work in physics might well extend over eight hours and the laboratory work over nine hours, for one year. If, however, the class of work done in the laboratory is of the usual physical kind it surely will have to be done again under the teachers of engineering, and the time given to the work could well be reduced to three hours laboratory work a week for a year, with the conviction that even that is too much to waste. Habits of exactness and absolute honesty should be carefully cultivated and, as early as may be, the student should be obliged to work out his problems in his own way.

The subject of Chemistry is one which can best be taught through the laboratory. I do not mean that the work should be entirely done there, as here again it is fundamental principles we are after. Every engineering student should do a certain amount of quantitative work as well as the general and qualitative chemistry necessary to prepare him for this. He does not need the large store of the individual facts which he could obtain from an extended course in general and qualitative work, but he does need a certain amount of manipulative skill to carry out quantitative work, and this he can best get in the laboratory. A careful individual class drill running parallel with his laboratory course, will give him sufficient chemical knowledge to prepare him fundamentally for his work as an engineer. In the quantitative work, the materials of any of the fields of engineering in general should be used for examples, as boiler scale, brick materials, storage batteries, gas, leather or coal. Common sense applied to chemistry is what is wanted, as none of us will insist that the student should carry away from this work more than the ability to use his common sense for chemical purposes when need arises. As to the time which should be given to this work, six to nine hours laboratory work, with two hours quiz or recitation and an occasional lecture, should cover the ground.

In Language, the work done in English should be thorough, largely by individual instruction, of the kind requiring the work to be done mainly by the student, and in amount at least equal to the minimum requirement for any technical degree now given in college. In modern languages it is not profitable to expend a large amount of time. The object of such a course for engineering students is to teach them to read rapidly and understandingly. No language study should be permitted beyond the amount required to accomplish the end, and when this is accomplished the work should stop.

One language properly taught is all that should be required, and it should be done in the time equivalent to three hours for one year. There is little, if anything, which can be called education in such teaching, and it is the one place in the education of an engineer where training should take the place of education. He should be trained to read French, or preferably German, that he may be able to read it; that he may use it as one would be trained to use a hammer to drive nails. Anything more, while perhaps desirable from an educational, is not desirable from an engineering standpoint.

We have now, probably, disposed of one half the time available in a four year's course in engineering, and in this there is little if anything which should not be prescribed. This is as much the foundation of any other engineering as of a mechanical course, and to most of us who are engineers, not teachers simply, the proper presentation of these subjects will make up for much that is not so desirable in the balance of the engineering course. In the engineering work proper, the course can probably be divided into four distinct divisions, although they are all to a large extent interdependent.

These are Drawing, Applied Statics, Applied Dynamics, and Specialties. Under the first of these, the writer would include all drawing-room work, beginning with the use of the instruments and ending with an engineering design of some kind, and requiring a considerable amount of work in the shops to complete it properly. Under the second head, should be included what is generally understood as mechanics of materials, kinematics and kindred subjects. Under the third head, should be included such work as electro-dynamics, hydro-dynamics and thermo-dynamics, from the standpoint of the engineer, including a large proportion of the laboratory work to be referred to later. Under the fourth head the writer would include such matter as a careful study, from all standpoints, of apparatus or plants which are well within the knowledge of the teacher, such as are commonly handled under the heads of steam engines and boilers, hydraulic machinery, electrical machinery, etc.

First, as to the course generally; it can be laid down as a proposition which, it is believed, cannot be successfully controverted, that the work done in an engineering college should be of the character which will benefit the student educationally, and that any other work should have no place in an educational system. The results to be obtained from such an engineering school is the development of engineering common sense. If this is successfully accomplished the results cannot fail to be satisfactory.

Before taking up in detail the work above outlined, there is one matter which occupies about the same relation to engineering work that modern languages do to the balance of such a course as we are now talking of. A short course should be given in engineering nomenclature. It should give the names of the parts of machines in common use, their functions, the materials of which they are made, and how they are put together. This should cover the apparatus in common use, mechanical, electrical and hydraulic, so that a student is rapidly trained to talk in the language of American engineering. Such a course as this could be completed in two hours a week for one-half year, and would be well worth the time spent on it. If possible, a satisfactory text-book full of sketches should be used, and students be required to copy the sketches, as well as to sketch other similar pieces which may be in use in shops and laboratories. The sooner a student comprehends how a machine works, the quicker he can understandingly grasp the general principles on which it is made and operated.

To come now to the course in Drawing. Work in the drawing room should continue throughout the entire four years of a course, but a student should be taught to draw in the first half year. He should first learn the use of the instruments, with absolutely nothing else to distract his mind. His work should be copy work, graded to cover the greatest use of the tools in the shortest time, and he should be obliged to do it as accurately as the teacher can himself. Insistence on the absolute accuracy and neatness of the work, which requires great diligence from the teacher, will in a surprisingly short time teach a student how to draw. As soon as this much is accomplished, the teaching of drawing, as such, should be at an end; inaccurate work thereafter should be rejected as a matter of course, and no excuse should be accepted for anything not well executed. This work can be completed in three hours for half a year.

This should be followed by teaching the student how to draw objects, and here, in connection with, or in place of, descriptive geometry, geometrical drawing and the proper method of placing drawings, making sections, etc., should be taught. This will probably take the balance of the year, say three hours a week. Lettering and figuring should be commenced during this year and continued, as a matter of course, thereafter. In the second year, he should be taught what to draw for engineering work. He should be furnished with sketches, just as one would make them in the shop, lettered, figured and drawn as badly as such sketches generally are, with instructions, at first, as to the proper uses of the drawings he is about to make, and then required to make working drawings, and these should be carefully criticized as to their being best suited to the work which is to be produced from the drawing. He has been using such drawings in the shop and knows what they are for. He should be obliged to do a certain amount of tracing and blue-printing, and given a little practice in such points as shading, coloring, and generally making drawings to be used by others than engineers and mechanics, all in connection with making working drawings for sketches.

The question may here be raised, why not allow him to sketch first, and make the drawings from his own sketches? A reason is that he has no idea what he is going to do with his sketches after they are made. We are trying to teach him two things at once, one the proper method of sketches and one the use to which the sketches are to be put, and on which the method of making them depends, and he can absorb one thing at a time better than two. The work above outlined, the using of the sketches, may take three hours per week for a second year. It does seem that the making of sketches is postponed until late in the course, but the fact is that sketch making has been carried along from the beginning of his course, all descriptive work being illustrated by sketches, pictures in many cases, but in many others good mechanical sketches without dimensions. The third year can be commenced by actually making sketches. A large machine tool, an engine, an actual boiler, any piece of apparatus in laboratories or shops may be used for this work. Let the students examine it and see it work; then apportion the work so that the entire machine is covered without duplication, and make each man responsible for his own share. Then have the machine taken to pieces, the sketches made in a limited time, have the machine put together, and require working and assembly drawings. Two pieces of work of this kind which can readily be completed in a year, three hours per week, together with the design work to be hereafter referred to, will teach a student to do all that is necessary up to the point where he can give his mind entirely to the production and designing of the apparatus he is studying. The work in drawing has now covered two years and probably a half, not over three hours a week, and hereafter the adaptibility and usefulness of the object drawn to accomplish its intended work should be the one thing looked after. The student by this time should be so far advanced in the parallel courses of study that the work in design can be satisfactorily carried on. By design is meant a careful study of existing machinery of the class dealt with, and an attempt on the part of the student to utilize all the knowledge he has or can obtain in producing a satisfactory design of apparatus to work under slightly different conditions. Slightly different conditions only should be insisted upon, as it is a minute study of existing machinery which should be attempted rather than an attempt to produce an original machine on paper.

It is here that the specialty of the teacher should be strongest. It is a matter of no moment whether an engine, a pump, a machine tool, a dynamo, or an engineering plant, is taken for the design, but, in whatever line the work is done, it should be handled as nearly as may be as an exactly similar problem would be handled in engineering works. How it is to be made, the minimizing of the cost of making and operating, etc., should have as much weight as the determining of the dimensions that it may do its work properly. While no one will claim that such a course of designing will teach a student to design, it will help to develop the critical faculty, that common sense which every engineer must possess in a large degree, and if the work is well done on the teacher's part, the results will be very satisfactory. With small sections and a teacher thoroughly understanding his business, this work can be well done in three hours a week for the latter two years of the course.

Taking up now the second division of the engineering work which has been called Applied Statics, the writer does not think anything can be a better guide than Rankine's "Applied Mechanics" as to the ground to be covered, although it is hardly practicable to use it as a text-book. With mechanical students the problems should be largely mechanical, taken from actual practice whenever possible, ideal conditions should be kept as far out of sight as possible, and the actual problems which have to be met, used for examples. The principles of statics and the theory of structures, can well be treated together. A student should be perfectly familiar with the elementary principles of statics from his mechanics of physics. Graphical methods should be used to as large, or even larger, extent than with a student who intends becoming a civil engineer. What is known as mechanics of materials, or mechanics of engineering, can be put in such shape that four hours per week in the class, with two or three in the drawing room, will enable the work to be well done. This work should be taught by one who has had not only an engineering education, but afterwards a practical, not college, engineering training. The proper relation between the book and the thing should be carefully observed. Formulas should be deduced last, the work should be with numbers continually, and exact results obtained. This particular division is fundamental, and every student should be obliged to master thoroughly this portion of the work.

A similar but shorter course in hydraulics and kinematics would probably require three hours for a year, with three hours of drawing. When these subjects are taught by the younger men in a department, the text-books should be strictly adhered to, and continuous drills be the method adopted. Every problem should be solved as though there were no text-books from which to obtain formulas, and it should be the teacher's aim to see that the subject is understood.

The third general division of the engineering work is Applied Dynamics, or perhaps it might be called the theory of machines. In thermodynamics, the laws governing the transformation of heat energy into mechanical work, and similarly for electro-dynamics and hydro-dynamics, are of course the objects. The principles can well be taught from text-books, and the application later in the laboratories will clear up much that is hazy in the class room. The amount of time which should be given to these subjects is perhaps fourteen hours a week for one year. Here again the fundamentals are what are desired, the principle of the conservation of energy being the all important consideration to be developed and impressed. The division of time will and should vary much with the text-books used and the personality of the teacher. Here again it is the engineering sense rather than the particular matter under discussion, which is to be developed, and not that the student should know the formulas of thermodynamics. Give him, if possible, a real living knowledge of what takes place in a turbine, a steam engine or a dynamo, the effect of altering details or methods of use, and he will be a better engineer. Make him think for himself, and to take nothing for granted which can be reasoned out, even if the professor of mechanical engineering does say it is so.

In this connection much of the laboratory work will be done. The classing of shop work with laboratory work, as is often done, is unfortunate and it does not seem that, as now carried on, the two are done with the same end in view.

Taking up the question of shopwork, how much time and what amount of prominence should be given to actual work in the shops? There is likely to be a very wide variation in the opinions of the different engineering teachers. Let us see what is the object of shopwork in an engineering school. Is it to make mechanics? It hardly seems possible, as the one element of doing the work at the least possible cost is not and cannot properly be taken into account in an educational system. If such is the object, it is an undesirable one and probably cannot be accomplished. Is it to turn out men who can save a part of their later time as apprentices? Then it is not worth the trouble. Is it to make a boy handy? Then a very little of this class of work will serve most students. Is it to educate the hands as well as the brain? In many cases if a student can do satisfactory work at the forge, or at the machine tools, or at the pattern-maker's bench, we are apt to think our shopwork has been a success.

Is it not a fact that satisfactory shopwork can be done without a particle of engineering education? One can train the hand to carry out many mechanical processes, but the real number of the fundamental ones in any trade is limited, and these may form legitimate portions of an engineering education. After this is done perfection comes by repetition. The combining of these processes with the aid of machine driven tools of any kind has little that is educational in it. If then we want education from it, we must take it from the usual shop course and put it into the laboratory.

To illustrate what is meant, suppose we have a student who has never worked on a machine lathe. He understands generally what the different parts are for, and has been through the process of centering, straightening and securing the piece for work, all of which may be educational. It is to be turned of a certain diameter for a certain length. Now what work has the student to do? To set the tool; he gets it right once in ten times perhaps, because he never has had to and probably never will have to get it out economically. He uses his calipers for determining when the piece is of the right diameter and of the right length. The student's work is done; the machine does the rest of it. Now he is given a piece of brass to work on and is told that the latter should run differently, the tool should be ground differently. He again sets the tool, probably incorrectly, runs it at probably the wrong speed, gets it the right diameter and length and has an idea that he has done it. So he has, but he can never get pay for doing it that way. The fact is that there is not enough business back of it all. If he is to be taught forging beyond the fundamental principles, let him take it as a specialty and learn it properly, for what is often done by many of us is to make him handy at the forge, a tinker with an exaggerated idea of the value of the facility he has gained.

It is not the purpose of this paper to go into the question very deeply, but the following is a statement of the writer's views. First, there should be two distinct classes of work done under the head of shopwork, one, that class of work which will be valuable in aiding a student in intelligent designing, the other of the kind which will teach him how to determine the relative value of different tools for doing the same work. These can be illustrated by two examples. First, in a course of wood-working, such a series of exercises should be devised as will give him in the shortest possible time the necessary skill to handle the tools and do a fair piece of work. At the same time require him to study such text as will make clear the reason why the tools he is handling are made of the material and in the shapes that they are. That is, while he is learning the use of the tools, he should be laying a foundation for a careful study of tools in general. As soon as a student has the ability to handle his tools fairly well, he should be required to take up a course in pattern making, and as soon as possible he should be required to lay out the work for himself. This course should be fairly thorough and the result should be that in his designing work, the question "How is it to be made?" should be asked almost in the same breath as the question "How large must it be?" and should be just as intelligently answered. It is doubtful whether more can be obtained from a course of shopwork in wood. A similar amount of work can be done in the other shops, with the distinct understanding that no work is to be done which does not teach the student something. We are still far from handling the question which we hope most of our students will have to handle in their actual work. The question of whether it will pay to cast it or forge it cannot be handled satisfactorily in a technical school, and this with the answer to many other similar questions must be obtained in engineering works.

A student, however, can be taught how to determine such questions as the proper speed at which turning or planing should be done to remove the most metal at the least cost with the apparatus at hand, to determine the best shape of cutting edges to do a certain class of work with the tools available, etc., and this is the class of work which is real laboratory work with shop appliances. Such work is as valuable, and may be made more valuable than almost any other class of laboratory work, and is the only legitimate object of a large equipment of machine tools in an engineering college.

This latter class of work comes properly under the term laboratory work, and for the balance which is properly shopwork, the time allowed need not be over fourteen hours, or perhaps twelve hours per week for one year. This work should be accompanied by frequent recitations, or examinations if you please, and should have the same weight and seriousness as any other part of a course.

To return to the laboratory work proper. The value of a course in laboratory work depends on how the work is done, rather than on what is done. Require a student to act on his own responsibility, not only as to the methods to be used, but even as to the details. Make him see that the apparatus is the right kind for his work, and that it is in proper condition. Any one can take readings if he has the proper preliminary training already alluded to under the head of physics. Of course one would not care to trust beginners to take readings of any kind without a reasonable amount of supervision, but this is a small portion of an engineer's work. His problems generally are the handling of new questions with unknown, and in many cases, with very poor apparatus. Laboratory work should be done in the way of setting certain problems to be solved. Say to the student "there is a laboratory full of apparatus, use your common sense to select the proper pieces for this work, see that your apparatus is properly set up, and report when you are ready." This work should all be done by one man, as divided responsibility means poor work somewhere. Then detail a certain number of observers, as few as possible, to assist until the work is done. Hold the experimenter responsible for every portion of the details. Require every observer to obey implicitly the directions of the experimenter, and the results will be more than satisfactory. There are two objections to be urged against such a method of doing work. The first probably will be that the student will do but little experimental work, in number of experiments certainly; but in value he will get the full equivalent of the time, and it is not what experiments are made, but how they are made, that counts. How many of us have seen students enough around a machine to carry it away, after an instructor or an attendant had prepared it for a test? Each student works up results and believes he has made that experiment. No experiment is too large to be done under the direction of one student, and if assistance is required, it should be merely mechanical; his should be all the brains used.

A second objection which may be made is, that this is an expensive method of procedure. That is true unless every piece of apparatus is utilized to its fullest extent. It means much wear and tear, and adds much to the difficulty of doing so-called scientific work in engineering colleges. Of course, it is not possible to give students complicated experiments to begin with, nor is it desirable. Take the large experiments, divide them into a number of separate parts, and require every student to do each part before handling the whole of it. It is not particularly desirable to work with large machines, and a large number of small, inexpensive ones will give more service in the way indicated than large intricate ones. The amount of time which can be well spent in this class of work will be perhaps fourteen hours a week for one year.

Coming now to the last division of our engineering work, that which has been called Specialties, it is probable that most of us lay too much stress on the particular ones that we handle. The idea underlying this division of the work is to show how the principles the student has been handling up to this time can be rationally applied to particular lines of engineering work. If a man's specialty is electrical work, let his work require an exact study of electrical machinery, the methods of producing it, the details of the designs, the economics in using it, and its application in the broadest sense. If it is steam engineering, let him assign the same close study of boilers and engines, carrying the work as far as the time at his disposal will allow. Bring it into his shopwork, his laboratory work, into kinematics and thermodynamics, so that a student begins to realize the serious business side of the profession he has chosen.

If the teacher's specialty is pumping machinery, let him use this in the same way, so that the course is filled with it from the beginning to the end, the idea being that it is far better to teach the practical things he really knows about, showing how engineering principles must be applied to bring success in one line, rather than to attempt to cover a number of lines of work of which he has no practical knowledge, and can only know second-hand that certain things should be so. For this work allow not over eight hours a week for one year, and this will fill in all the time one has at disposal in a four-years' course.

This division of time is based on a course extending over four years, each of which includes thirteen to sixteen hours per week in laboratory, drawing or shopwork, as well as fifteen recitations, or lectures, per week, each of which requires at least an hour's work outside of college.

In this no allowance has been made for thesis work, in the belief that it is simply a special piece of laboratory work, and should be handled as such.

No reference has been made to shop visiting, as it should be handled under the division of specialties. It may be done as follows: Not over two students are sent to any one place at the same time. Specific questions are given them to consider at each visit and definite reports on these questions are required, their attention being specially called to the importance of the matter under discussion. The students must think for themselves, because descriptions only are not satisfactory; opinions and good reasons therefor are required.

In a few cases, it is possible to increase the time to five years, and when this is the case, the additional year's work should be in that portion of the course which is not distinctly engineering. If it is found necessary to omit any portion of the work, no attempt should be made to reduce the hours given to the earlier divisions of the subject, but the divisions of the work should be omitted, beginning with the last.

Before closing, a few words as to who should carry out such a course as is here outlined, may not be out of place. We are all prone to take bright young men just out of college, and attempt to train them to become engineering professors. This is a great mistake if their work is to be only with students, as they do not and cannot, see the college work in the proper perspective; to be good engineering teachers, they should have the corners rounded off by rubbing against men and things. It is wise, if such a man is desired as an assistant, to require him, or at least advise him, to reduce his vacation to four weeks and use the rest of it in learning to be an engineer.

Finally, the object of such a course is to develop men of sound engineering common sense, and of absolute integrity, who have such fundamental knowledge that they can enter any field of mechanical engineering, and with the amount of industry necessary to success in any line, become successful engineers.

Herewith is added a table showing the division made in the body of the paper.

	Class. Hours.	Laboratory. Hours.
Mathematics	10	
Physics	8	3 to 9.
Chemistry	2	9 to 6.
English	6	
Modern Languages	3	
Nomenclature	2	
1 (Drawing and Designing)		12.
2 (Applied Statics and Graphics)	4	2 to 3.
2 (Hydrostatics and Kinematics)	3	2.
3 (Applied Dynamics,	14.	
3 (Shop Work)		12 to 14.
3 (Laboratory Work)		14.
4 (Specialties)	8.	
Total	54	54 to 60.

TEACHING INDUSTRIAL APPLICATIONS OF ELECTRICITY.

BY GEO. D. SHEPARDSON,

Professor of Electrical Engineering, University of Minnesota, Minneapolis.

The large number of students pursuing courses in electrical engineering makes it a living and perennial question, what will become of them? Is it to be expected that as only a small proportion of the vast number of law students ever earn a livelihood in the legal profession, while the great majority use their legal education as a help to success in other pursuits, so the majority of students in the electrical engineering courses will ultimately drift into some other occupation? It certainly is true that many of the students in engineering courses have undertaken them without careful investigation of either their own fitness to become engineers, or of the path by which success may be acquired. Some are utterly unfitted to become engineers, having neither the ability, nor the perseverance. Some have the idea that if they are too lazy to be farmers, too slow and dull to be successful in business, or if they have not had and will not get education and culture enough to follow a so-called learned profession, they may become engineers. They may become threshing-machine engineers, but they would do better to save the time and money spent in trying to become what they were never intended to be. Others have been fascinated by the attractive experiments with electricity during their course in the high school or elsewhere, and, as they always liked to see wheels go round and sparks flying, they would become engineers. Others argue that everything can be done quickly by electricity, therefore they will study the mysterious force and get rich and famous quickly.

One of the early duties of the instructor is to give the prospective engineer as clear an idea as may be that, while there is some satisfaction and some advantage in being a good engineer, success comes only after long and thorough training. One must have a taste and talent in that direction; must be able and willing to perform a great deal of hard and unromantic work, sometimes for twenty-four or even sixty hours at a stretch, must carry heavy responsibilities, control men and work, do the work of three or four men at times, and "be up early and always at it." A plain talk of the above nature to those who are entering the course will be beneficial both in persuading some of the idlers and indifferent students to seek other spheres of activity, and also in inspiring the better students to more earnest and unremitting work. A common experience is that engineering students, like others, do not realize the importance of thorough preparation until their technical course in the school is far along toward the close. The occasional non-resident lecturers will furnish excellent corroboration of the instructor's advice by giving the students actual examples of what an engineer must be, bringing ideas fresh from the industrial world, and outlining some of the problems to be faced and the methods of dealing with them. The present writer believes that the engineering students should be impressed early and often with the truth that engineering is a responsible and honorable calling that involves much hard labor and a thorough preparation. With such a truth in mind, the students are not so prone to waste their time and opportunities.

After the engineering student has mastered the physics of the freshman and sophmore years and has learned something of the general principles and phenomena of electricity, he should be given some insight into its industrial applications. A satisfactory method is to take up the phenomena in about the same order as treated in the class in physics, indicating the various purposes for which they may be utilized. Particular attention is given to actual applications, showing the steps of development, the present state of the art and manufacture as indicated by the latest information available. Numerous references are given to papers upon the subject, care being taken to include those of the current month or volume. With samples, pictures and inspection trips, the ground is covered with some satisfaction in a course of ten to fifteen lectures. The aims of this introductory course are to enlarge the vision of the student, to show that the two or three applications with which he may have been acquainted, are only a small part of the whole, that in many directions much has been learned and more remains to be discovered, that some fields are promising although apparently neglected, that the investigator finds many open doors for research, and that new processes or industries may be developed after much study and labor. From such an introductory course, the student may obtain a better idea of the opportunities before him, he is assisted to some extent in choosing the special line of work for which to prepare himself, and he can follow more intelligently the development of theory and practice in the remainder of his technical course. After developing this idea for several years, the writer is convinced it is wise to give the students a brief bird's-eye view of the whole field of electrical engineering before going into details of any special branches.

It is the general custom of the engineering colleges to give the students a considerable acquaintance with electrical engineering practice by judicious selection and use of apparatus in the laboratory, by study of actual problems in class and on the drawing board, and by occasional inspection tours. A helpful practice that may not be so common is to encourage students to spend their vacations in factories, repair shops, electric light and railway power-houses, with contractors, or wherever else opportunity may allow, in order to obtain some commercial experience. In some case it is advisable for students to spend an entire year in this way before their last year's work in the university. By this means their eyes are opened to the real meaning of their work and study, they appreciate better the true relation of their technical training to their lifework, they naturally put much more efficient study upon their class and laboratory work, and not the least, they exert a far-reaching beneficial influence upon their classmates and the junior students.

The writer thoroughly believes in combining theory and practice. Pure abstract theory is very good for some people and for some purposes. But for training an engineer who must deal with realities and not abstractions, it is essential to illustrate theory by practice that he may wisely guide his practice by theory, and then temper his theory with practice.

A COURSE IN MINING ENGINEERING.

BY REGIS CHAUVENET.

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The subject is naturally divided into:

(1.) Location and Equipment of the institution.
(2.) Subjects and Courses.
(3.) Methods of Instruction.

While a part of this paper treats the matter from a general point of view, it will hardly be possible to avoid some special references to the Colorado State School of Mines, of which the writer has had charge since 1883.

Before taking up any of the topics above indicated, mention must be made of the lack, in many applicants, of general education and scholarship, a lack which we are compelled to recognize as the great weakness of the engineering profession to-day.

There is no time in the technical college to impart general education, but there is time before entering it. This is no place for the discussion of the maze of modern methods and subjects. The object should be the power of apprehension and expression. The engineer who can best give form to his ideas, by speech or pen, will rapidly rise above his fellows.

Experience has shown that the most successful students are those who come best prepared in English, and thus best equipped to acquire, whether from text-books or from the lips of the lecturer. A fair mastery of their own language should be made a *sine qua non* of admission for all applicants.

Examinations to determine this point are not easy to regulate without working injustice to some applicants. Locally our experience is that more than one third of each Freshman class fails to enter the Sophomore year, and that these failures are to be attributed chiefly to lack of general training. A smaller number fail because of apparently inherent inability to grasp the elements of mathematics or descriptive geometry. Of those "quitting" in the first year, less than one third ever return.

Such being the limitations, by no means confined to one school, of the material presented, we do not care to enter into a discussion as to ideal conditions. If our preliminary "roasting" is insufficient, as it seems to be, we trust to the next operation to remove the worst of the impurities.

Location and Equipment.

The location of a College of Mining is more important than its immediate equipment. In a broad sense, it is its best equipment, if it be a favorable one, while no equipment can be a substitute for mining and metallurgical environment. This statement applies more to a mining institution than to one of general applied science. A mining region remains such for centuries, and its accompanying smelting and reduction works form a necessary part of its commercial success. In a country whose chief interests depend upon the development and maintenance of mines and the treatment of ores, the very atmosphere favors the acquisition of knowledge of practical utility in such lines. To speak of the Colorado School alone, a million dollars in equipment would be a poor exchange for its proximity to mills, smelters and mines of every variety, whose operations and methods serve, as the case may be, for examples or for warnings.

As to local equipment, that is the most useful in proportion to cost, which has grown from actual and even pressing demands from year to year. It is safe to say that when great sums are expended in advance, serious errors will be committed in respect to the actual working value of the equipment purchased, and that undue relative weight may be attached to certain classes of equipment which subsequent developments may show to be superfluous. A fine thing, for example, is a museum of a quarter of a million specimens, classified and displayed. But it may not be so fine as ten thousand specimens in the hands of a class, lectured over, handled and tested.

It is better for a student to make a sulphuretted hydrogen apparatus for himself out of an old pickle jar than to tap the gas ready-made from a pressure reservoir.

A first-class equipment is not to be undervalued, but some aids to learning as presented at certain institutions seem to remove all incentive to ingenuity on the part of the student. However, there can be little divergence of opinion as to the more desirable points. Every institution which aims to give a mining course either has or has in view substantially the same appliances, whether in machinery, instruments, laboratory apparatus or collections; these being taken for granted, the topic may be closed by returning to the original statement that location is after all the chief factor.

SUBJECTS AND COURSES.

In a course in mining engineering, we include the whole of the metallurgical course. This being understood, the foundational studies of the course must be mathematics, chemistry, physics, mineralogy and draughting.

These are called foundational because they can be acquired properly only during early years in school, while their applications may be, and have been, mastered after entry into active life. In the following details the courses are outlined as given at the Colorado School, by no means as model or ideal courses, but as the outcome of ten years' experience and trial, under certain limitations.

Draughting may end with the Sophomore year, so far as instruction goes. Descriptive geometry should be mainly disposed of in the Freshman year. The draughting of the upper classes should be directly in the lines of machine design and metallurgical work, serving at once as instruction in these lines and as practice in draughting. Three hundred and seventy-five hours are given in the Freshman year, exclusive of descriptive geometry, and two hundred and twenty-five in the Sophomore year. The Juniors have about two hundred hours in designing; the Senior work is not scheduled, but is always greater than in the Junior year. Lettering is practiced from the first, and of late free-hand lettering has been brought into a systematic course of instruction.

No marks are given in draughting; a plate is either accepted or rejected. A fixed number of accepted plates must be handed in by each student. The schedule hours are often exceeded by individuals, who may remain in the draughting room after regular time, light permitting.

General chemistry starts with the opening of the Freshman year. Physics naturally precedes chemistry, but in a course which is to include metallurgy, chemistry cannot well be set later in the general course. Since, however, the mathematics of the Freshman year is needed in physics, the latter has to be assigned to the Sophomore year. This is mentioned only as a local necessity, not of general application. Five lectures or recitations are given each week in general chemistry, the elements of the necessary physics being introduced in the earlier part of the course. It is not until April that the Freshmen enter the laboratory for qualitative analysis. They have about one hundred hours of this work during the term, also attending lectures on laboratory practice and chemical equations, in addition to the general course which still continues. This total is considerably exceeded in the Sophomore year, the fall and winter terms being occupied by laboratory work in the afternoon, but the class drops the work in April, to resume it as Juniors the next fall, the hours still growing, so that it may roughly be given as follows for the entire course:

Freshmen, general chemistry		200	hours.
"	lectures on practice	20	"
"	laboratory practice	100	"
Sophomores,	" "	150	"
Juniors	" "	200	"
Total		670	"

There are in addition, advanced lectures on chemical theory, not included in this time schedule. In the B. S. course, several hundred hours more are taken; this is not given in detail, as not being a mining course proper.

For three of the five regular terms this course does not materially differ from that ordinarily given in most colleges of applied science. In the Junior year assaying is taken up, including much that would not popularly be so classed. Analyses of slags are made a specialty. Rapidity is cultivated as soon as this can be done without sacrifice of accuracy. Gravimetric methods are given for everything, but are not repeated to a great extent in those cases where volumetric work can be substituted. The volumetric methods systematically taught, are those for silver, copper, lead, arsenic, iron, manganese, zinc and calcium. In fire work, each student checks on about two hundred assays for silver and gold, though this number is usually exceeded. For lead and copper a less number is accepted.

As the number of commercial checks on hand usually numbers several thousand, it is not difficult to keep a whole class busy on widely differing samples. Assays are never marked. They are either practically perfect or they are absolutely rejected. Silver and gold assays are done in batches of sixteen as a rule, copper by fours or sixes. The aim is to send students directly, as practical chemists and assayers, to mines or smelters, and this being frequently done brings, of course, swarms of applicants for this line of work alone. These, however, are declined, as are applicants for any line of work except the complete course. The number thus refused admission annually is somewhat over double the number admitted to the regular course.

The course in mineralogy and geology is not continuous, though this is a mere matter of convenience in schedule. Mineralogy runs through the entire Sophomore year. It occupies nearly two hundred hours, but as the amount of individual instruction is large, the class is divided into sections, except for general lectures. The work is very largely in the laboratory, and as it is a "popular" branch, the hours in determinative work are often exceeded. There are many examinations, oral during the term, written at its close. Nearly all of these are examinations upon the actual minerals. Collections include beside musem, "type" and "working" sets, crystallographic classifications, local collections, and other special arrangements, some devised for the illustration of economic geology. Lecture models are in glass, laboratory models in wood. It is not thought necessary to particularize in mineralogy, as it is probable that the course does not differ from that of any institution at which as much or more time is devoted to it.

Geology occupies three hours a week during the Senior year, exclusive of a considerable time devoted to field excursions; in fact, it is because the Senior schedule is adapted to greater allowances in this respect, that geology is assigned to it, though it is believed that it should in any case be placed in that year. Collections of classified rocks are studied throughout the course, which is directed as far as possible to those questions relating to economic production, ore deposits, coal fields, and, in short, all topics bearing upon mining.

The course in Mathematics being, as to ground covered, the same in nearly all of our technical colleges, need not be discussed at length. In the more mechanical portions, exercises in the use of logarithms should be given frequently enough to render the use of the tables a mere matter of course. The same may be said of the use of formulas. It is a very striking phenomenon to see, as we have all seen, how difficult it is for the average student to pass from the enunciation of a principle to its simplest application. Try this for an example so obvious as to be almost ridiculous, and you will realize it with any class. For instance,after all the members of a class can solve a right-angled triangle, tell them that one boy stands just one hundred feet under a kite, and a hundred feet from the boy who holds the string. In a class of fifty there may be found from five to eight who will not be able to see any hypothenuse in the case. This suggests that it is useful to render simple applications familiar as we go, not trusting too much to the student to see them at first for himself. There are few instructors who do not err in this respect, especially in their first attempts in class. The very common assertion that little use is made in practice of much of the mathematics taught in the colleges is true; but the reason for it is probably as much in the lack of clearly demonstrating the actual applications and insisting upon them as part of the work in class. It is, however, as a gauge of capacity that we would more especially speak of the uses of mathematics. Two faculties inborn mark the man who will become a successful mining engineer. One we cannot measure in the college, the other we can. The first is that power of personal magnetism which enables the most ignorant man to serve as a medium for investment or enterprise. If he be honest it is well. If he be a liar it is better, for his career will be far more brilliant in the proportion in which there are more bad investments than good ones. But the other faculty is capacity for mathematics. It may be applied or it may not, but it can be cultivated and gauged. Rare indeed are those cases in which incapacity for mathematics is accompanied by great talent in anything else. In it, then, we have at once a study necessary and exponential, a guide post, a map and a motor. Inscribe on your doors as did the Greek scientist of old, "Let no one enter who is ignorant of mathematics." Grade by it. Accept in other lines the excuses of handicaps, of well-meant effort, of probable amelioration in the future, but let mathematics stand as the stern ironclad monitor, uncompromising throughout the courses, whom to pass is indeed success.

In passing from foundational to special work, we stop at the word "special" to speak of that much vexed individual who has become a question, the special student. First remarking that he no longer vexes us at the Colorado School, for we abolished him except as a post-graduate in 1891, it may be worth while to discuss him on general grounds for the benefit of those who willingly or unwillingly still cling to him.

The European idea of allowing students to "specialize" while in school is unsuited to this country. A boy must take a job which presents itself. He cannot often choose, and cannot rise from one position to another in commercial life, unless his training has been broad onough to enable him to accept varied work. Nor can a man be a trustworthy specialist without the good judgment derived from a broad training in other branches.

European students are usually so narrow as to be under a terrible handicap in any work outside of their specialty. Many have we met, and not a few of them trained in Europe, who will say "Amen." Briefly, then, before a man can become a "special," he must have something to "specialize" in.

Locally, the abolition of special courses met with severe criticism, and many prophecies of immediate falling-off in students. Result, the doubling of the number in two years, followed by a very decided rise in the standard of work and amount accomplished, and finally a recognition of the institution by the mining and metallurgical interests, which testify to the improvement in method. In June last twenty-four were graduated. In August every one had secured some position, several very good ones, some of course in humbler lines, but all were at work.

A "B. S." course has been organized which omits mathematics in the Junior and Senior years, as well as those engineering lines requiring Junior mathematics, but devotes greatly increased time to chemistry. The work for this degree begins in the Freshman year, where a record of 90 must be shown in chemistry.

This must be maintained in the Sophomore class, together with 80 in both physics and mineralogy. It is probable that few will take this degree, not because of the record required, but because those who can make such a record will also be good in mathematics and will take the E. M. degree. It has been found that to enter men for a non-mathematical finish was to guarantee failure, unless the material was exceptionally good.

The relation of civil and mechanical engineering to mining engineering, and the amount of time that should be devoted to these subjects in a mining course, are questions not yet to be answered in full. It does not seem to be practicable, perhaps it is hardly necessary, to give what would be called full courses in the former lines to mining students. Granting that it is our duty to prepare students for useful work immediately following their graduation, and still to give them a broad understanding and training in all the branches of their chosen profession, it remains to be seen in what way civil and mechanical branches are related to mining engineering, and then to lay stress upon these parts.

The mining engineer who is required to lay out claims, make surveys of property and mines, or locate sites for plants of various kinds, must have a thorough course in surveying. As he may be called upon to take charge of hydraulic mining works, with their tunnels, ditches and conduits, as well as to build tramways to mines in inaccessible parts, the surveying must be extended to embrace the planning, estimates and construction of these works.

A knowledge of theoretical and applied mechanics is as necessary to the mining as to the civil or mechanical engineer. The application of mechanics to designing should be carried out along the lines of civil engineering only far enough to make the student familiar with the usual methods of construction; for this purpose complete designs should be made in timber and iron of simple forms of roof truss and bridge. The course in dynamics should be followed by, or embodied in, a short course in machine design, including complete designs and working drawings of some simple forms of machinery. With such preliminary work the student should be able to understand and make simple working drawings and be prepared to undertake intelligently, during the latter part of his course, the design of the more difficult plants and works connected with mining and metallurgy.

The mining engineer should have a knowledge of the properties of cements, mortars and building stones, and their methods of use in construction. Only the simpler forms of masonry structures and foundations should be taken up, but these thoroughly and with working plans and estimates of cost. A broad understanding of hydraulics should be given, especially the parts relating to the flow of water in pipes, ditches and tunnels, the general theory of hydraulic motors, extended to include water power development with estimates and tests of efficiency.

A knowledge of the theory of the steam-engine is necessary to the mining engineer to enable him to choose, from the various types on the market, that which will best answer his purpose. It is no less useful for him to be able to remedy some of the evils of poor management in existing plants; to this end the course should be as practical as possible, including the testing of engines and boilers, with discussions of the advantages and disadvantages of various types.

Recapitulating, we advise:

Surveying (recitations and lectures)	100	hours.
“ (field work)	280	“
Theoretical and applied mechanics:		
Kinematics, dynamics, statics (lectures and recitations)	100	hours.
Machine design (lectures)	30	“
“ “ (drawing)	125	“
Strength of materials (recitations and lectures)	75	“
“ “ “ (testing laboratory) at least	40	“
Graphics (recitations and lectures)	30	“
“ (drawing)	40	“
Structural designing (lectures)	20	“
“ “ (drawing)	50	“
Masonry structures and foundations (lectures)	20	“
“ “ “ (drawing)	30	“
Hydraulics and hydraulic motors (lectures)	30	“
“ “ “ (drawing and laboratory)	40	“
Steam-engine (recitations and lectures)	25	“
“ “ (boiler and engine testing, firing, etc.)	40	“

The above course of study and work should be arranged to be taken as early in the general course as possible, thus preparing the student for a better understanding of his own professional work during the Senior year. Much of the schedule given, however, comes almost necessarily in the Senior year, especially in its first half.

Coming to physics and electrical engineering, the instruction in physics should be similar to that given in mechanical or civil engineering. Optics and acoustics, however, are not dwelt upon to any great extent. The greater part of the time is devoted to mechanics, heat and electricity, as the growing importance of the latter subject has rendered it necessary at probably every scientific or technical college to increase the hours devoted to it.

Physics begins with the Sophomore year, four lectures a week throughout the year, and one entire afternoon of each week being given to laboratory work.

The electrical engineering courses in transmission of power by electricity, and the laboratory course in electrical measurements, have been greatly modified to meet the requirements of mining students. Electro-metallurgy, hitherto a neglected line in the colleges, starts with a systematic course for the coming session.

The increasing use of electrical power developed from water power has made the subject of electrical power transmission of great importance to the mining world. This application is in its infancy in Colorado, yet already more than 4,000 horse power is thus transmitted at mines and mills. This subject is taught rather from the economic than the theoretical side. After full discussion of the different systems, practical problems are presented, with data drawn from actual cases arising in mining and metallurgical practice in the State. The relations at various points of cost of transportation, fuel and other elements of total expense, are very fully given, and questions involving the comparison of steam, water, air and transmitted electrical power are freely discussed.

So many of the students of the Colorado School have worked in mines or mills that it is a substantial advantage to their classmates who have not had such practical experience to be associated with them. This comes out perhaps as much in the line now under discussion as in any other.

Besides the ordinary work in electrical measurements, some time is given to making the simpler measurements by means of voltmeter and ammeter methods, measurement of faults and their location. If the superintendent of a mine or mill can instruct his dynamo-tender how to test for grounds and crosses, and how to locate these faults in a few minutes by means of station instruments, much valuable time may be saved.

The Electrical Course proper as scheduled, will be here given; the regular course for E. M. degree omits most of the battery work, and much of the designing in electrical machinery. The distribution of electricity for lighting is also omitted, as is photometry. Transmission of power and the testing and discussions already given are as much for the mining students as for the candidates for electrical degree. The references to time are for the aggregate of the last two years of the course, Junior and Senior:

Primary and secondary batteries (lectures and laboratories)	85	hours.
Electrical measurements (laboratory practice)	50	“
Designing of electrical machinery	200	“
Dynamo electrical machinery (lectures)	150	“
“ “ “ (laboratory)	150	“
Electrical magnetism (three fourths laboratory time)	100	“
Electric power transmission	25	“
Photometry	50	“
Dynamo testing	40	“
Transformers	25	“
Distribution of electricity for lighting	25	“
Shopwork	300	“

The electrical course includes part of the course in metallurgy and most of that in mining. It also takes in the whole of the course in hydraulics. These details are mentioned simply to indicate that the course is specially designed for application to mines and mills.

The course in hydraulics and in steam engineering is so closely connected with the electrical, both in the general and electrical courses, that it is found difficult to make the schedules entirely separate.

It will be noted that much of the work described has so direct a relation to mining that it may be fairly said to form a part of it. The titular courses, mining and metallurgy, have been reserved for the last; these will be treated so far as possible apart from their engineering features.

It has been the custom in most American colleges of mining, until recently, to treat the subject of metallurgy almost wholly by lectures. For this there was, indeed, much excuse, the lack of good text-books being notorious. This, however, can no longer be alleged. General and special texts are now available, and systematic assignment of reading matter can be made, an advantage which will no doubt be appreciated alike by professor and student. The lecture system will certainly not be abandoned, but each lecture will assume that all details given up to date by the text have already been mastered.

The principle of broad training applies in metallurgical instruction. For instance, an engineer is not equipped to originate, improve, or do the highest class of work in lead smelting, unless he is acquainted with the metallurgy of iron and steel.

There are four main divisions of processes to be considered:

Iron and steel.
Smelting processes.
Ore concentration.
General milling and wet processes.

Within each of these main lines the various processes are so intimately related that a *detailed* study of one or two makes it unnecessary to spend much time on the others.

It does not pay to plunge into the details of processes until general principles and typical operations have been mastered. For instance:

The effect of impurities.
The principles of refining.
Study of alloys.
Thorough study of combustion and use of fuels.
Refractory materials.
Furnace construction and classification.
Classification of processes.
Electrolysis and electro-metallurgy.

Austen's Introduction to Metallurgy is a great help in giving a student this thorough grounding. The time required is not wasted, but more than saved in the rapidity with which processes are afterwards mastered.

Lectures in metallurgy number in all about two hundred and forty, but it is essential to bear in mind that the reading matter is almost additional to this, and that examinations and tests have reference to both lecture and text matter. Trips to the typical plants of the regions are inseparable from the general scheme of instruction. The arc lantern is in constant use, over one thousand plans, details and working drawings having been put on slides, a collection which of course is continually being increased and supplemented. This method, giving over twice the linear dimensions of the largest working drawings, has been found admirably adapted to the metallurgical lectures; also, though not to so great an extent, to illustrating mining plants and surveys.

Metallurgical design has already been mentioned under the general head of mechanical draughting. Its direction belongs to the chair of metallurgy.

Mining as an art is merely the practical solution of the problem how to get there with the least expense in the least time. Each locality has solved it for its own conditions. No single mine or single district in the world illustrates the entire art of mining. Most mines are operated by methods which have been evolved to meet local conditions. Sometimes these methods have resulted solely from the hard sense and business experience of the operators, who have paid little or no attention to the experience of other parts of the world. In other cases these resources are aided by the highest engineering skill, applied to the particular needs of the district. To know the mining art of to-day, therefore, we must ransack the world for the best in each department.

Usually, mining is done in the most simple and direct way, and with the least possible equipment. Any makeshift is adopted that will save money and do the work.

Average western mining comprises a few simple operations, the elements of underground work every-where. Only at a few isolated mines is it necessary to call upon the higher resources of modern engineering. It is a great help to the student to be familiar with these standard operations while at college. Occasional visits to neighboring mines give this familiarity. If he can get an underground job during vacation it is an advantage, though such jobs are scarce and hard to find.

The importance of such work, however, has been absurdly over-estimated. Opportunities for it do not often occur until after college life and to men of much physical strength. The work of the common miner teaches but little of the broad knowledge required by a mining engineer. That little is rapidly and easily picked up after the student leaves college and begins practical work at a mine.

There are nevertheless certain advantages in having begun a career by pounding a drill. One is the impression made upon the minds of mining men, who generally attach more importance to this record than to a diploma. The other is the acquaintance with and knowledge of common miners, which can be acquired only in this way. Usually the students step from college in something better than tramming or drilling. It is therefore needless to begin at the bottom of the ladder, when a higher round is offered at the start.

It must not be forgotten that nine tenths of all mining skill is the ability to find ore. This is particularly true of mining for the precious metals. Owners and investors are unable to judge of technical ability, and judge by results alone. So long as the mine is in pay ore it is quite immaterial whether the superintendent knows an ore chute from a transit. The study of ore deposits is, therefore, the most important feature of mining education. This, however, cannot be well begun before the student has acquired a thorough knowledge of petrography; he must be familiar with rocks and rock minerals in every stage of alteration and decomposition.

The chief texts used in metallurgy and mining are:

Austen's Introduction to Metallurgy.
Peters' Copper Smelting.
Eissler's Metallurgy of Silver.
Rose's Metallurgy of Gold.
Hofman's Metallurgy of Lead.
Hughes' Coal Mining.

METHODS OF INSTRUCTION.

We are satisfied that the lecture system has been overdone. It is excusable only in the absence of proper text-books. Personal instruction is slow, and life is short. Elementary details should be acquired by the student. The lecture and the individual instruction in the laboratory or work shop should be reserved for points requiring elucidation after the text, not of points which the student should know already. The objects then of personal instruction may be thus summed up: To make difficult principles clear; to select the grain from the chaff; to bring the student up to recent improvements in practice which may not have found their way into the texts; to give the student an insight into the views and practical methods of an experienced professional man.

It may as well be acknowledged that the average student will not work steadily, unless held down to regular study of some text-book, and checked by an occasional "quiz" or written examination.

The note-book question is important. Students are not advised as to the proper function of notes. It has been often said that very few students ever use their notes in practical life. The remark indicates a very erroneous idea of the supposed use of the note-book. The use of notes is to aid the student in acquisition during term work; it is not expected that he will compile a reference library for practice use. Notes are a great aid in review studies, also in recording matters not found in the text, but the student would do well to bear in mind that what he chiefly takes out of college is his brain, fortified by what he remembers of facts and principles, and he may about as well throw his note-book into the fire on graduation day.

The lecturer is not fair to his class who does not indicate the matter on which it will aid them to take notes. Thus many students become slaves to the note-taking habit, trying to write down without discrimination all that they hear, while others abandon the attempt in despair.

In the chemical laboratory the most important part of personal instruction is the training of the beginner in proper laboratory habits; in avoidance of waste of material and of time, and in the minor points well known to every working chemist. The students pay a fixed fee for chemicals, and for apparatus according to the amount broken.

In draughting the instructor is always present, ready to assist in cases of doubt or difficulty. In mineralogical testing the professor is present, but as the object is to identify species of elements with certainty, the only assistance given is to tell the student that he is right or wrong as the case may be, and if right he must give an account of his operations and reasoning.

Examinations are frequent. Those at the close of the fall term are meant to determine for many students whether they can with profit continue in their grade for the remainder of the session. At these examinations usually about one fifth of the Freshman class is dropped, though most of these leave in fact before the actual test. About one tenth of the Sophomore class is relegated to the Freshman year at the same time. It is thought to be far better to render judgment thus early in the second year, than to allow an unfit man to drag along without real profit only to be displaced at last. No student can enter the Senior class under conditions to be made up.

Athletic sports are encouraged. The students are allowed their own organization which controls the gymnasium and all field sports.

There are no printed rules, and very few rules of any kind, for the regulation of students. There are no punishments or penalties short of absolute dismissal. A dismissal is final, but is a very rare event. Discipline, in the ordinary sense being unknown, the general conduct and order are excellent.

These details of one mining course and institution are given to suggest discussion ; not as dogmatic dicta as to methods or courses. They are the outcome of certain requirements, coupled with several limitations;

a different condition would, of course, have produced another result. As the strongest deduction from the trials of a decade, the abandonment of special or partial courses must be mentioned.

My thanks are due to Professors C. B. Stewart and L. C. Hill for data as to their courses in engineering and electricity respectively. I am especially indebted to Professor E. B. Kirby for remarks on the mining and metallurgical work and on methods of instruction.

Discussion.

Prof. Heinrich O. Hofman said that there were several points which occurred to him in this paper, which might perhaps be of special interest. The author said that location was of more importance than equipment. Of course, the location of a School of Mines in a mining district is important; when it came to metallurgical work the student may see metallurgical operations, but he can not do any of the work or perform any of the experiments himself. Therefore, it seemed to him that a properly equipped metallurgical laboratory is as much an absolute necessity in a college of mining engineering in a mining region, as in one away from such a region. If the choice were given him between a good location and a laboratory, he should always prefer the laboratory, provided he had a summer school. There was another point, in regard to general chemistry. The author said that chemistry is taught by lectures and recitations, and that students enter the laboratory only when they begin their qualitative analysis. At the Massachusetts Institute of Technology, laboratory exercises come in connection with the general chemistry, and seemed to him most important to aid the students in understanding chemistry. He thought it was not right to teach chemistry without taking the student right into the laboratory and putting him through a systematic course of chemical experimentation. In regard to what the author said about no longer having special students in assaying, the speaker remarked that when he was in Colorado in 1883, some of his friends spoke to him in regard to the Colorado State School of Mines. This college had all the opportunities of location, but had suffered a great deal by having these special courses, and became more successful only when it abolished them and really began a systematic course of teaching. In conclusion, he could not agree with the author of the paper on the question of notes. If the student, as soon as he was through the course, ought to throw his note-book into the fire as the best manner in which to dispose of it it must be the fault of the instructor in not teaching him how to make notes in the right way.

THE EQUIPMENT OF MINING AND METALLURGICAL LABORATORIES.

BY HEINRICH O. HOFMAN.

Associate Professor of Mining and Metallurgy in the Massachusetts Institute of Technology, Boston.

The mining and metallurgical laboratory, as we understand the term in this country, is a place in which mehanical and chemical working-tests are made on ores, fuels and furnace-materials. It is of quite recent origin. The first laboratory of this kind to be used in connection with teaching was put into operation in 1871 at the Massachusetts Institute of Technology.* The idea had already existed in the mind of President W. B. Rogers when he wrote, in 1864, his pamphlet on "The Scope and Plan of the School of Industrial Science of the Massachusetts Institute of Technology;" but several years elapsed and an extended visit to the mines and mills of Colorado, Utah, Nevada and California was required before this idea could take a form adapted to the purposes of original research as well as of instruction. The laboratory was given from the first into the charge of Prof. R. H. Richards, who, by improving its methods and enlarging its scope, has brought it to the position which it occupies to-day as the leading representative of its class. Private laboratories for making tests upon ores had previously existed here and there, especially on the Pacific coast, for silver and gold ores; but in the educational field the Massachusetts Institute of Technology was the pioneer. To-day there is hardly a school of mines in this country that has not a more or less complete mining and metallurgical laboratory. In European mining schools there is very little laboratory teaching. Most of them are located in mining districts, where the students can personally see and engage in the practical work of mining, concentrating and smelting. Those which are in large cities, at a distance from mines, labor under a great disadvantage. The student only sees practical work when he makes an occasional visit to mining regions, and is otherwise left entirely to theory. It must not be inferred, however, that the location of a school in a mining district can make the laboratory superfluous. On the contrary, one who, like the present writer, has received his training in such a school, sees clearly afterwards how one-sided becomes the teaching in a mining district without the addition of such laboratory work. The instructor is only too liable to give most, if not all, of his time to elaborating unnecessary details of the local methods, past as well as present, and to pass over with amazing celerity those branches of the subject not represented in his district. Yet even as regards local work, upon which he puts such undue stress, he is likely to be too theoretical, because not being practically engaged in it, or able to apply such tests as are furnished in the laboratory, he necessarily falls into too abstract a way of viewing the whole subject. The result is that his instruction tends to produce theorists, who speak with unwarranted assurance concerning the most diffcult problems which the engineer has to solve; but who, if confronted with a simple, concrete quession, are at a loss what to do.

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* R. H. Richards, *Transactions American Institute of Mining Engineers*, i., 400.

That this lack of laboratory training in German technical schools (which are among the foremost in Europe) is beginning to be realized as a defect, was evidenced by the intense interest and careful study bestowed upon the subject by the commissioners who came to the Columbian Exposition two years ago. They did not hesitate to praise our system and to express the hope that it might be adapted to meet their necessities on the other side of the Atlantic.

The mining and metallurgical laboratory, then, as developed in this country, may be considered a necessary adjunct to every school of mining engineering. In it the lecture instruction is illustrated with practical experiments, carried out by the students themselves. But it has also a larger scope. By the method of experiment the student learns how to take hold of each problem as it presents itself and carry it through the different stages until it is, or the reason is discovered why it cannot be, satisfactorily solved. He is thus taught to observe closely, to make careful notes, to compare the results obtained and draw his own inferences and conclusions, and, finally, to report what he has done in clear and accurate language.

In fitting up a laboratory we have to consider only the departments of mechanical concentration and metallurgy. Practical mining can be taught only in the mine. Some schools (for instance, the one at Ballarat, Victoria, Australia) are provided with a model of full natural size, showing a shaft with the lode cross-cuts, etc. While this, apart from the question of expense, is an improvement on the small models formerly so extensively found at schools, it cannot but give a false impression of what a mine really is. The practical study of mining, in this country at least, is carried on to-day in "summer schools." The students spend some time in mines, going systematically through the different kinds of work, and thus becoming sufficiently familiar with mine operations to listen understandingly to lectures on the subject. It is the merit of Prof. H. S. Munroe, of Columbia College, to have given to the summer school of mining such an impetus that to-day there is hardly an American mining school without this auxillary course.

Before discussing in detail the equipment of a laboratory, it is desirable to consider the relation which the laboratory plant should bear, as regards general arrangement and the kind and size of apparatus, to the large-scale working plant of actual practice. A commercial concentrating works, for example, must treat daily a considerable quantity of ore, and must work cheaply, which can only be done if the machines are so connected with one another that the ore shall receive a minimum amount of handling after the work is once under way. In the laboratory, on the other hand, the work, being purely experimental, must be carried on, step by step, in a deliberate and tentative way; and it is therefore essential that the operator shall be able to inspect the material under treatment before and after every operation. Consequently, the machines must be separate, that they may be easily accessible for starting, stopping, accelerating and retarding, and may be connected at will; in short, that the work may be modified indefinitely under the immediate eye of the experimenter. A laboratory in which this principle is neglected carries in it the germ of failure. The writer was once connected with such an establishment, in which a full-sized ore-dressing plant had been erected according to the plan followed in commercial work, viz., the crushed ore was raised by a bucket elevator to a set of screens placed in a line step-wise, one discharging into the other, and the sized products falling directly upon the jigs and the table below. Of course, a few tons of ore were quickly disposed of, but when the products obtained were examined after the experiment, the observer did not know very much more than he had known before. Such a working plant may be of some value for obtaining more adequate quantative results after all the necessary details have been determined by the use of detached machines, but it will do little more than substantiate what has already been sufficiently proven.

There are two opposite views concerning the kind and size of machinery proper for laboratory use. One holds that it should follow as closely as possible that of a working plant. The other maintains the superiority of somewhat different and smaller apparatus as better suited to experimental purposes, and also more economical. Having tried both kinds, the writer decidedly prefers the latter, especially for educational purposes, and is of the opinion that there are few mechanical questions to which a machine smaller than the commercial size cannot give a satisfactory answer. In addition to economy, convenience, and other considerations, the saving of physical strain upon the student secured by the smaller apparatus is of importance. Fatiguing operations, especially for those unaccustomed to the work, exhaust the powers and unfit the student for mental effort.

The best size for the single machine can only be arrived at by repeated trials, which have now been made for almost all given cases, as will be shown later on.

In the discussion of the details of a laboratory, it will be more profitable to start from the basis of an actual working laboratory, whatever may be its defects, than from an imaginary perfect one. The laboratories of the Massachusetts Institute of Technology, shown in plan in Fig. 1, may well serve this purpose.

The following are the different rooms, pieces of apparatus, etc., referred to by numbers in Fig. 1. In the present paper numbers enclosed in brackets are to be understood as referring to this figure.

1. Milling room.
2. Blake Challenge rock-breaker.
3. Cornish rolls.
4. Gates rock-breaker.
5. Hendrie-Bolthoff sample-grinder.
6. Iron sampling-floor.
7. Cornish feeder.
8. Automatic feed-trough.
9. Richards *Spitzlutte*.
10. Coarse Collom jig.
11. Fine Collom jig.
12. Convex continuous round table.
13. Hendy Improved Challenge ore-feeder.
14. Stamp-battery.
15. Amalgamated plates.
16. Frue vanner.
17. Richards' movable sieve-jig.
18. Water tanks.
19. Steam-drying tables.
20. Bucking-plates and Taylor hand-crusher.
21. Sampling table.
22. Ore-bins.
23. Pounding block.
24. Upright engine.
24.1. Morrell agate mortars.
25. Dynamo, 50 V by 50 A.
26. Dynamo, 2 V by 50 A.
26.1. Revolving barrel.
27. Depositing table.
28. Leaching tubs.
29. Larger amalgamating pans.
30. Small amalgamating pans.
31. Settler.
32. Tank.
33. Space to grow in.
34. Storeroom.
35. Blacksmith's drilling-machine.
36. Carpenter's bench.
36.1. Ball-mill.
37. Assay room.
38. Students' desks.
39. Pulp balances.
40. Muffle furnaces.
41. Crucible furnaces.

42. Stack.
43. Iron table.
44. Balance room.
45. Button balances.
46. Storeroom.
47. Storeroom.
48. Furnace room.
49. Blacksmith's forge.
50. Anvil.
51. Blacksmith's table.
52. Water-jacket blast-furnace.
53. Furnace ore-bins.
54. Brückner roasting-cylinder.
55. Copper refining furnace.
56. Large hand-roasting reverberatory.
57. Roasting-stall.
58. Cast-iron kettle.
59. Larger cupelling furnace.
60. Small hand-roasting reverberatory.
61. Small cupelling furnace.
62. Pot furnaces.
63. Space to grow in.
64. Professors' laboratory.
65. Table for electrolytic work.
66. Experimental *Spitzlutte*.
67. Chemical desks.
68. Hood.
69. Blow-pipe room.
70. Tables.
71. Cases for apparatus, etc.
72. Sink.
73. Library.
74. Bookcases.
75. Space to grow in.
76. Table.
77. Professors' desks.
78. Lithographic notes, etc.
79. Toilet room.
80. Lockers.
81. Basins.
82. Closets.
83. Professors' room.
84. Stack.

These laboratories are located in the basement of the Rogers building, the main building of the Institute, and comprise the entire department of mining, engineering and metallurgy, with the exception of the lecture-rooms and collections. While at first* all the metallurgical work, including dry-assaying, was done in the room marked [48] and the milling-work in the space now covered by machines [13] and [16], there are to-day a separate furnace-room [48], an assay and balance-room [37, 44], a milling-room [1] and a blow-pipe room [69]. To these may be added two storage-rooms [46, 47], a toilet-room [79], a library [73] and the private laboratory [64] and office [77]. Upon closer inspection, it will be seen that the apparatus is pretty closely crowded. Although there is some "space to grow" [33, 63, 75], and there are places near [1] and [33] still open, there is little room for additional permanent machinery, the available space being necessary for erecting temporary apparatus and giving room to move about in. A laboratory built to-day with a liberal allowance of space and of funds would probably be planned somewhat differently as regards general arrangement, and would also possess a larger amount and variety of apparatus. The work in it would be easier and could be more conveniently and quickly, but not better, done.

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* R. W. Raymond, *Statistics of Mines and Mining*, 1874, pp. 499 and 500.

In discussing the machines and furnaces, sufficient data will be given to enable the reader to form a clear idea of the relation which the laboratory apparatus bears to that used in large-scale work.

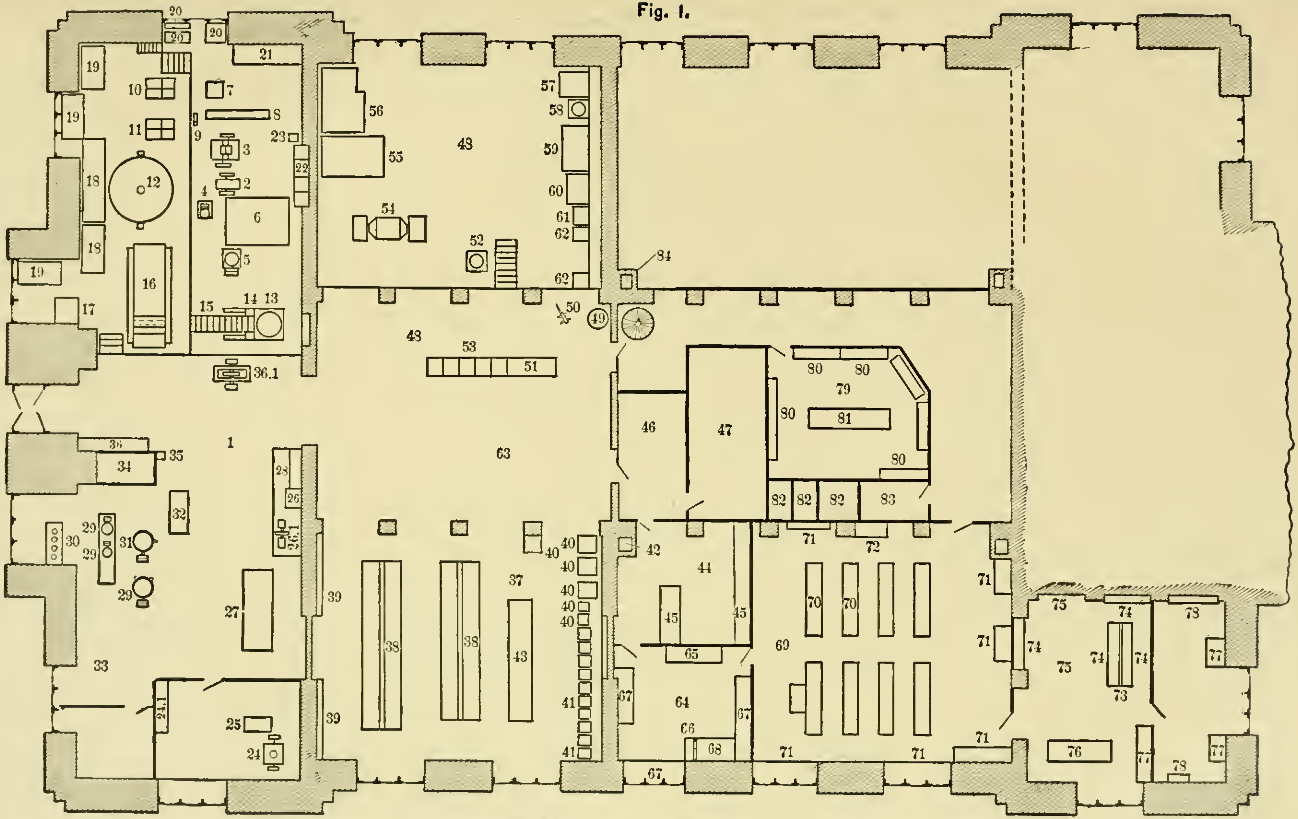
The apparatus of the laboratory is best classed under three heads, corresponding with its purposes:

A.—Concentrating.
B.—Sampling and Assay.
C.—Métallurgical.

A.—Concentrating Apparatus.

1. *Coarse Crushing.*—Coarse-crushing is represented by the Blake Challenge rock-breaker [2], with a receiving capacity of 4½ by 5 inches, and the Gates rock breaker [4], with a receiving hopper 12 inches in diameter. The machines are at a sufficient height above the platform to allow a wheelbarrow or bucket to be placed below the discharge. A pipe, connected with a small suction fan, serves to carry off the dust, if desirable. The Blake is used for crushing lump

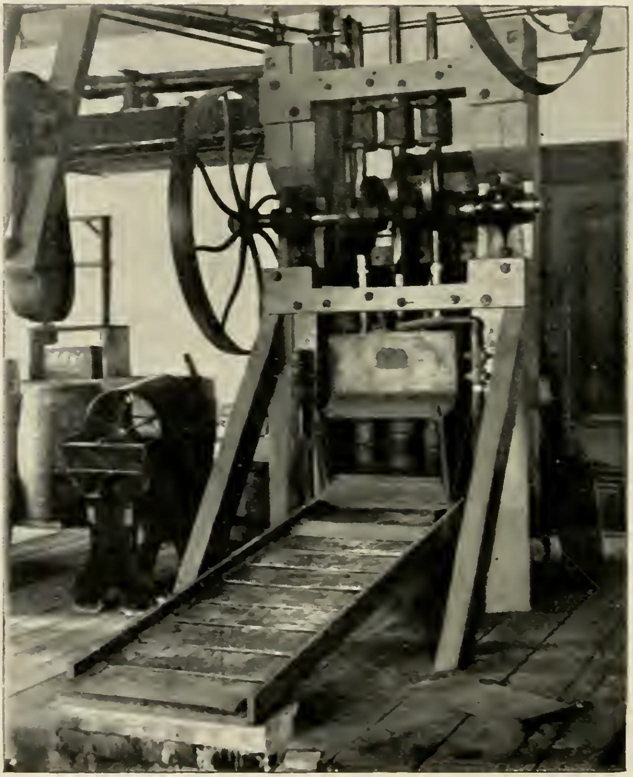
Fig. 1.



PLAN OF JOHN CUMMINGS LABORATORY OF MINING ENGINEERING AND METALLURGY.

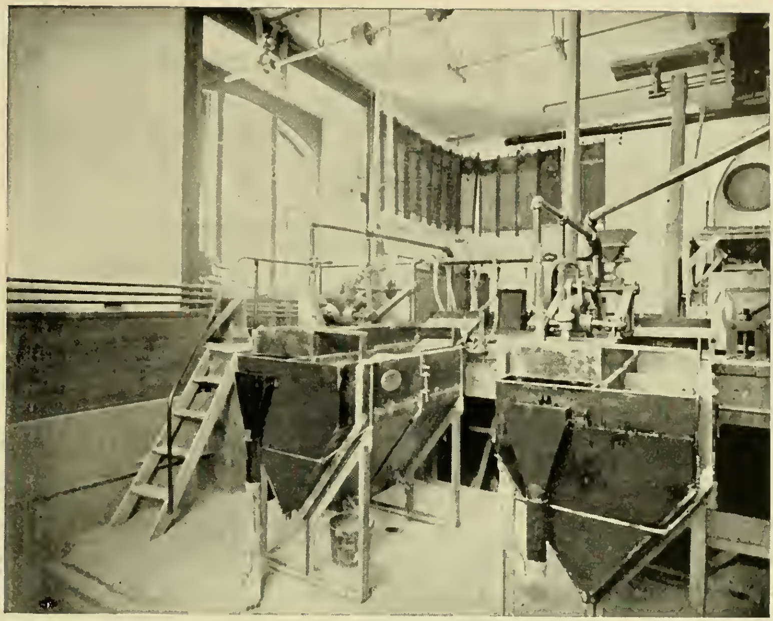
Am. Bank Note Co. N. Y.

FIG. 2.



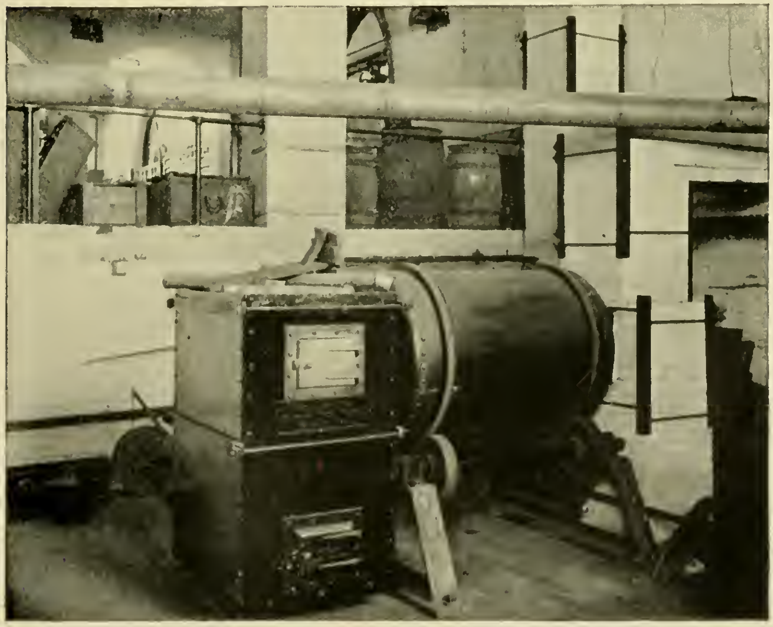
Stamp-Battery and Amalgamated Plates.

FIG. 3.



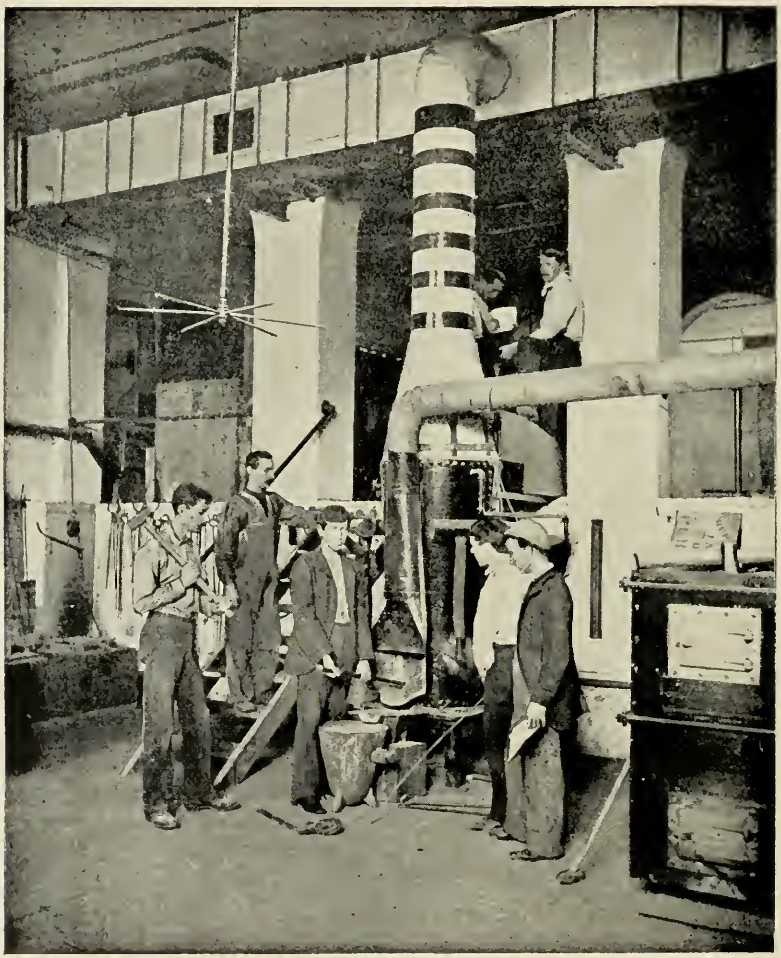
A Pair of Two-Sieve Collom Jigs.

FIG. 4.



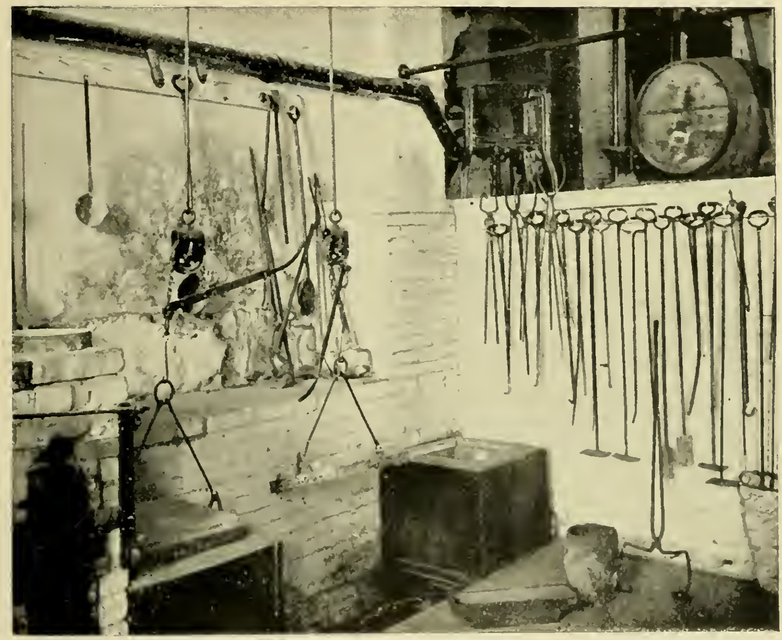
Brückner Roasting-Furnace.

FIG. 5.



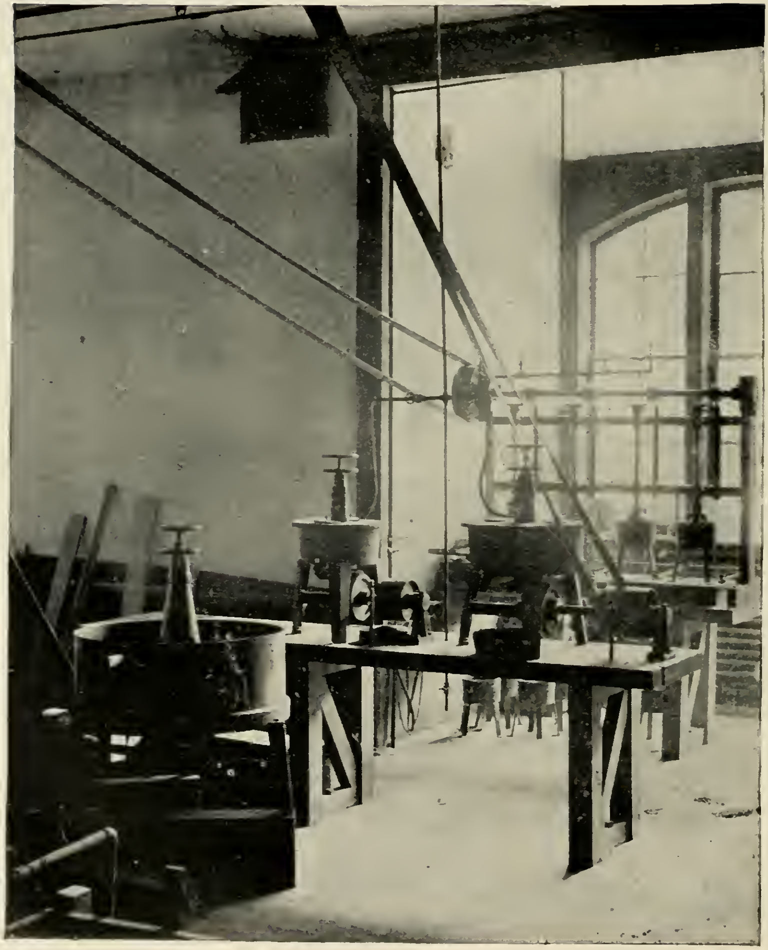
Water-Jacket Furnace for Smelting Lead and Copper Ores.

FIG. 6.



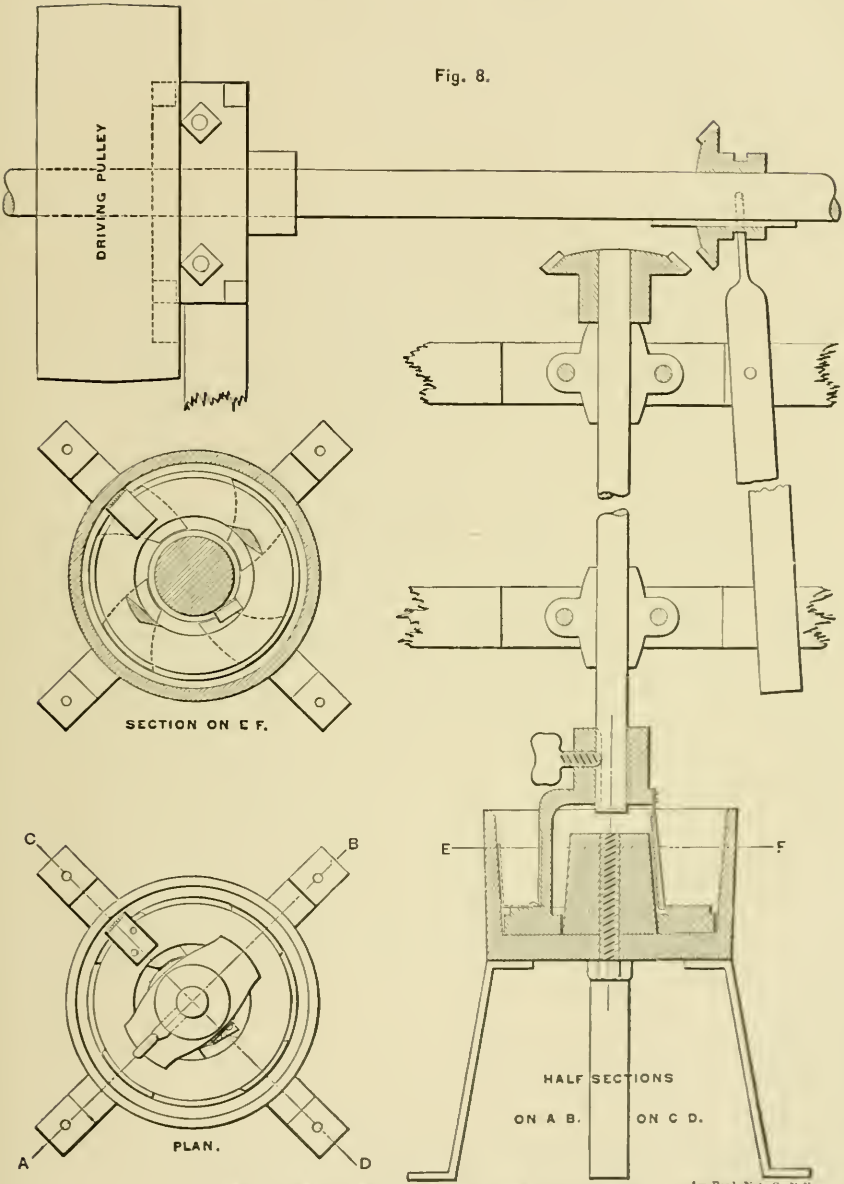
Furnaces for Pot-Melting, with Travelling Lift for Covers.

Fig. 7.



Laboratory Amalgamating-Pans.

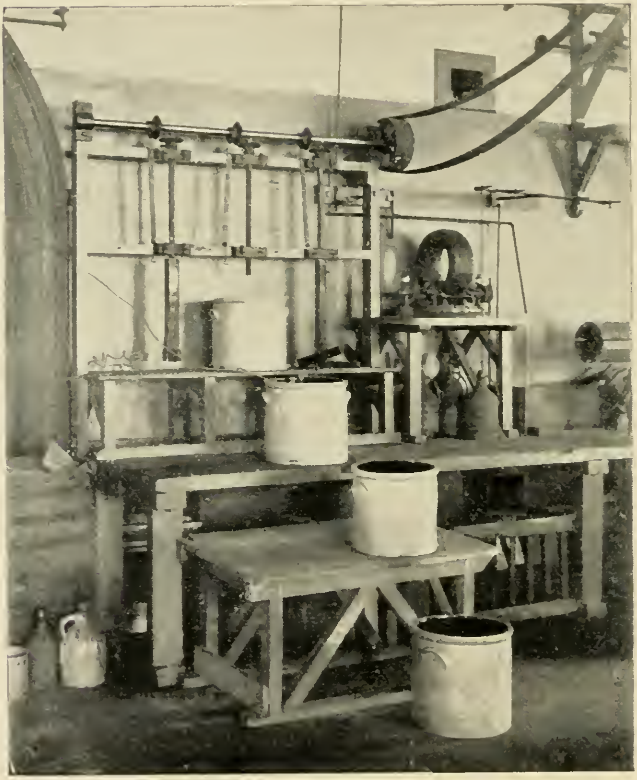
Fig. 8.



RICHARDS LABORATORY AMALGAMATING-PAN.
SCALE: 2 inches = 1 foot

Am.Bank Note Co.N.Y.

FIG. 9.



Leaching-Tubs Arranged for Mechanical Stirring.

ore, the jaws being set 1¼ inches apart; the Gates for smaller sizes, the liners being set at ½ inch. The Dodge and Lowry crushers may be added to the plant if it is desired to crush ore more uniformly than can be done with the Blake or the Gates type; but this will hardly be necessary for the testing of ores, although it might be useful for illustrating class work. The small Taylor hand-crusher [20] is very convenient for breaking up specimens.

2. *Fine Crushing.*—For fine crushing there are a pair of Cornish rolls, a stamp battery, a non-discharging ball-mill, sets of pans, a sample-grinder, and bucking-plates.

The Cornish rolls [3], 9 inches in diameter and 9 inches in face, are of chilled iron, without the outside shell so common for large-scale work; are driven by direct and cross belt, and make 70 revolutions per minute. The pressure on the sliding box is maintained by springs. The rolls have a large feed-hopper, with adjustable discharge-slot, holding about 100 pounds of quartzose ore. The crushed ore is directed by three converging pieces of sheet iron (a short, steep one at the back, and a long, flatter one on either side) towards an oblong opening, 5½ by 27 inches, through which it drops into an oblong sheet-iron box, 14 by 36 inches, of No. 22 iron, with sides 6 inches, and ends 4 inches deep. The upper edges of all sheet-iron boxes or vessels used in the laboratory are bent around a ¼-inch iron rod to give them strength, and are painted with asphalt varnish. If the ore is to be screened, an oblong wooden screen-frame, 54 by 11 inches inside dimensions, made of 2½ by ⅞-inch wood and closed at the upper end, is suspended in a slightly inclined position from four iron ($\frac{5}{16}$-inch) hooks from the wooden frame of the rolls, and oscillated by an excentric of 1-inch throw and 200 shakes per minute, driven from the main shaft below. The ore drops upon a piece of sheet iron, 11 by 12 inches, in the upper end of the frame, passing over which it comes to the screen (54 by 12¾ inches). Through this the finer parts fall into a sheet-iron box, while the coarser ones are carried over into another which adjoins the first. The screens are fastened to the lower sides of their frames by means of angle hoop-iron and screws.

The crushing capacity of the rolls per hour is 600 pounds of quartzose ore to ¼-inch size, or 300 pounds to ⅛-inch, or 150 pounds to $\frac{1}{16}$-inch. While they serve their purpose for fine crushing, as a preliminary operation in ore dressing, yet, if ore is to be rolled previous to chloridizing and leaching, Krom rolls are very desirable for finishing, the Cornish rolls serving in that case as roughing rolls.

Roller mills, such as the Huntington, Griffin and Tustin, or discharging ball-mills, such as the Brückner, while doing satisfactory work in dry and wet rolling, are better suited for the mill than the laboratory, on account of the difficulty of cleaning up.

The stamp battery [14 and Fig. 2] is of the California pattern. It has the usual single-discharge mortar for wet crushing, but only three stamps; the weight of the stamps is 228 pounds; the mortar bottom is 19¾ by 6 inches; the depth 5 inches; the discharge surface 20 by 10½ inches; the screen frame 21½ by 13 inches; and the screen surface 18⅞ by 9¼ inches. The cams permit the lifting of the stamps to a height of 8 inches. The rate of crushing Nova Scotia gold quartz with a 7-inch height of discharge, a length of drop of 5¼ inches and 98 drops per minute is 3353 pounds in twenty-four hours, or 1 pound for every 4198 foot-pounds developed. With a 7½-inch drop and 60 drops per minute, it is 2117 pounds, or 1 pound for every 5816 foot pounds. The coarsely crushed ore is fed to the battery by a Hendy Improved Challenge Ore-Feeder [13]. A double-discharge mortar, of which one side can be closed by an iron plate, will soon replace the old mortar, so that in the laboratory it will be possible to do both dry and wet stamping. In planning a new mill a battery with three stamps would not be chosen. The choice would lie between a 5-stamp battery of light stamps, say 300 pounds each, a 1- or 2-stamp battery, the stamp weighing 750 pounds, and a steam stamp. The 5-stamp battery has the advantage that the same number of stamps is used as in common practice. It would not be feasible to have a full size 5-stamp battery, as it entails too much work and requires more ore than is convenient and suitable for experimental work in the laboratory. The 1- or 2-stamp battery with 750-pound stamps dropping in a narrow double-discharge mortar, one side of which could be closed at will, the discharge to be on a level with the base of the die and to be raised by chuck-blocks to 16 inches, and the stamps to have a length of drop of from 4 to 10 inches, would be very acceptable. The results obtained with it would resemble very closely those of large-scale work. As to the desirability of a steam stamp for laboratory use, the writer feels himself at present unable to express an opinion.

The other fine-crushing apparatus, such as the ball-mill, the pan, the sample-grinder, the bucking-plate, etc., will be discussed under the heads of sampling and metallurgical apparatus.

3. *Sizing.*—The sizing or sifting of ore is more tedious in the laboratory than it is in the mill, because the screening surface is necessarily smaller, and all sifting has to be done without the use of water. If there is only a moderate quantity of ore, the sizing is best done by hand on a platform covered by an iron plate [6]. Sieves with wooden frames from 24 to 18 inches in diameter, and iron or brass wire gauze having 4 to 20 meshes to the linear inch, are well suited for this purpose. With very small quantities of ore, nests of sieves with metal frames, 8 inches in diameter, and wire gauze ranging from 20- to 120-mesh are convenient, the screenings to be caught in a metal pan. With large quantities of ore the sifting has to be done by machinery, and the shaking sieves referred to above, are used for this purpose. There are fourteen of these, representing the sizes 2-, 4-, 5-, 6-, 8-, 10-, 12-, 16-, 20-, 30-, 40-, 50-, 60- and 80-mesh. They sift per hour about 2000 pounds of 8-mesh ore, 1000 pounds of ore ranging from 14- to 30-mesh, 300 pounds of 50-mesh, and about 150 pounds of 60- to 80-mesh material. As this work is somewhat slow, it is better to do it in separate sizing boxes. Two inclined boxes, having screens of 3-, 10-, 18-, 30- and 60-mesh, and 4-, 8-, 14-, 24- and 50-mesh respectively, are satisfactory for the purpose. They are made of ½-inch pine, are

90 inches long, 18 inches wide and 5 inches deep, and have wooden covers screwed down on a felt band. They are oscillated 200 times per minute by an eccentric and connecting rod, which gives them an end-shake. The ore is fed into the hopper at the upper end, and drops on a piece of galvanized iron, whence it passes on to the first (the coarsest) sieve. What is too coarse to pass, strikes a dam at the opposite end and is discharged into a vertical spout at the side, to which a cloth bag is attached, through which it passes into a pail. It would seem as if the Coxe gyrating screen, which does such excellent work in sizing all sorts of minerals, might well be suited for laboratory purposes, either in the form of a single screen or a nest of screens. The trommels, as commonly employed in large-scale working plants, are out of place in a laboratory. If a trommel is to be used, the polygonal form seems the most suitable, as the different screens could be easily adjusted and removed. It would be necessary in all cases to house the trommel.

4. *Hydraulic Classification.*—Hydraulic grading is done at present in the Institute laboratory only in an ascending current of water. Grading in a horizontal current of water, or *Spitzkasten*, will shortly be introduced, as it has been proved to be indispensable for the successful working up of fine slimes. Now the fine sands and slimes are only settled, but not graded. Hydraulic classification is practiced with small samples of finely pulverized ore, as a preliminary test before working small lots. The samples are treated in the Richards pointed tube,* where the mixed sands,

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**Transactions American Institute of Mining Engineers*, xxiv., 438.

held in equilibrium by an ascending stream of water, are by slightly slackening the current, drawn off slowly into the glass bulb, which, when filled, is exchanged for another. The contents of each bulb are then separately sifted through a nest of graded sieves, and weighed and examined, to find out just how effective the work has been, and what will be the best sieve size for the trial test. In working, the material, after it has been crushed to the proper size, is passed through the automatic feed trough [8], or the Cornish feeder [7], into a Richards *Spitzlutte* [9], when the discharge of the spigot will go to the jigs [10 and 11] and the overflow either to the vanner [16] or the slime table [12], or first to the former, and as tailings, to the latter. It is proposed to have the overflow, when worked directly on the slime table, run first over a *Spitzkasten*, and then to feed separately the spigot discharge, thus insuring better work. Another way of using the Richards *Spitzlutte* is to feed only carefully-sized ore, when the spigot in many cases will give clean heads and the overflow clean tailings, provided there are no included grains. The capacity of the *Spitzlutte* with a ½-inch spigot is about three-quarters of a ton of sized material to one ton of mixed material per hour.

The automatic feed-trough and the Cornish feeder serve to convert dry pulverized ore into liquid pulp, delivering it to the *Sptizlutte*, the jigs or the slime washers. The feed-trough is of wrought iron, 10 inches wide at the top, 3 inches at the bottom, and 7 feet long, and is placed in an inclined position on a wooden trestle. On the inner side the trough is marked off, so that the same quantity of ore may be washed down by the travelling jet in the same interval of time, which is usually one minute. The travelling jet is a $\frac{3}{4}$-inch iron pipe, pointed downward and fixed in a wooden truck, having two of its wheels on one edge of the trough and the other on a rail 3 inches away from the opposite edge. The pipe is connected by a rubber hose with the water main. The carriage is pulled up the inclined trough by a weighted cord running over a pulley at the upper end of the trough to a shaft near the roof, around which it is wound once or twice and kept taut by the weight. To this weight is fastened a second cord, running over a pulley near the roof to the lower end of the trough, which serves to raise the weight and thus to lower the carriage. In order to prevent the rubber hose from obstructing the upward travel of the carriage and the even flow of the water, it is suspended from the rail by small grooved wheels, and the loops are replaced by 6 iron-pipe return-bends. Thus the suspended hose shows three zigzags, which are close together when the carriage is at the lower end of the trough, and separate as it travels upward, but are held together at the upper ends by strings which do not allow them to get more than 24 inches apart.

The Cornish automatic feeder is a four-sided truncated pyramid of sheet iron. It is 24 inches high, and the bases are 18 and 12 inches square. To the smaller base are attached four legs, on which it stands in a sheet-iron box, 16 inches square and 6 inches deep, contracted at one end into a spout. The legs (pieces of angle iron) firmly connect the hopper and the box, leaving the distance of ½ inch between them for the ore to pass through. This is charged into the hopper and washed down the spout by a jet of water playing usually between the walls of hopper and box, but occasionally (if especially quick feeding is desired) upon the ore in the hopper.

5. *Jigging.*—The jigs in use for water sorting are plunger-jigs and movable sieve-jigs. The former are represented by two Collom jigs [10 and 11 and Fig.3], used for ores ranging from 30- to 5-mesh, the latter by a Richards jig [17] for sizes larger than 5-mesh.

The Collom jigs are two-compartment machines. They are supported by a V-shaped iron frame on either end. The screen frames are 12½ by 18½ inches. The length of stroke is adjustable to ¾ inch and the number of strokes can be varied by the use of three step pulleys, 8, 10 and 12 inches in diameter, from 130 to 180 per minute. The ore coming from the feed-trough, the feed-hopper or the spigot of the *Spitzkasten* travels over the jig, while the tailings at the opposite end are collected and unwatered in a sheet-iron box. From this they are drawn at intervals, while the water which overflows, goes into the water tanks [18]. The jigs have no automatic discharge for concentrates, since, for the purpose of instruction and experiment, it is better to stop them every little while and skim off the different layers formed. The manner of working, therefore, is the same as that of large-scale one-compartment jigs. The reason for having a two-compartment jig is that "every machine, as far as practicable, should have its guard."* Any middle product

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*Richards, *Transactions American Institute of Mining Engineers*, xxii., 701.

not remaining on the first sieve will be collected on the second sieve, and thus prevented from passing off into the tailings. The Collom jigs here described were put in to replace two three-compartment Harz jigs formerly in use, the screen frames of which, 16 by 12¾ inches, were much too small to do satisfactory work. The reciprocating motion was derived from an eccentric adjustable to 2 inches, and the number of strokes could be varied from 100 to 200 per minute by four step-pulleys, 6, 7½, 9 and 10½ inches in diameter. The jigs had an automatic side discharge for heads.

The movable sieve-jig serves to illustrate the lectures, to work ore coarser than 5-mesh, and to do the water sorting in graded crushing and jigging. The sieve frame is 14 inches wide, 22 inches long and 12 inches deep; the ore bed can reach a depth of 10 inches. The rods of the screeen frame, ¾ inch in diameter, are divided into two parts to facilitate taking the machine apart. The two lower or jigging rods, 48 inches long, are forked at their lower ends and have an eye at the top through which passes a connecting rod, ¾ inch in diameter, suspended from the upper or eccentric rods, which are 25 inches long. The eccentrics are adjustable to 2 inches; the eccentric shaft is 51 inches long and 1⅝ inches in diameter. It has a conical pulley with seven steps, its smallest diameter being 6 inches, its largest 8¼ inches. The number of strokes per minute ranges from 100 to 200. The counter shaft is placed 14 inches above the eccentric shaft, and the whole is attached to a strong wooden frame. The water tank in which the ore is jigged, is 33 inches long, 27 inches wide, and 22 inches deep. Small boards extending from the sides into the tank serve as guides for the screen frame. The hutch-work is drawn off at the sides; the tank rests on a wooden box, and its top is 36 inches from the floor.

6. *Slime Washing.*—Of the different machines in common use for working slimes (*i.e.*, material not coarser than 30-mesh) only two are represented in the laboratory; a Frue vanner [16] and a convex continuous round table [12], a greater variety being excluded by the lack of space.

The Frue vanner is of normal size, *i.e.*, it has an inclined rubber surface 4 feet wide and 12 feet long. Either plane or corrugated belts are used. The normal adjustment for full work in the laboratory (inclination of belt 3½ inches in 12 feet, travel of belt 32 inches per minute, and 195 shakes of 1-inch throw per minute) has to be changed, if the pulp flows directly from the light three-stamp battery upon the vanner, as the battery furnishes only about 1½ tons of pulp in twenty-four hours, while the normal rate of the vanner is 5 tons. The simplest way is to change the inclination to 2½ inches in 12 feet and to regulate the flow of water accordingly. If the vanner is to do full work, the pulp from the battery is collected in the settling tanks and fed at the required rate and with the necessary water by the Hendy feeder of the stamp-battery. In order to permit this, the connecting rod of the friction plate is replaced by an eccentric rod, the eccentric of which has a 2-inch throw, and is on a small counter shaft near the ceiling. The counter shaft is driven from the upper shaft of the laboratory and makes 100 revolutions per minute. The ore which is fed by the carrier plate is washed by a jet of water into a sheet-iron trough and conducted from behind the mortar into the ore spreader of the vanner.

The convex continuous round table is 8 feet in diameter and has a slope of $\frac{3}{4}$-inch to the foot. It is of $\frac{1}{8}$-inch sheet iron, painted with tar, sanded and rubbed smooth, and is supported by an umbrella frame. It receives its pulp from a fan-shaped distributor, which discharges against one side of a central cone, 14 inches high and 18 inches in diameter, and its wash water on the opposite side from a horizontal curved pipe with perforations on the inner side. The three products, tailings, middlings and heads, flow into a circular launder. The compartments for heads and middlings are 12 inches wide and hopper-shaped; that for the tailings is 6 inches wide. The heads and middlings are drawn off at intervals into a pail; the water of the heads compartment overflows into that of the middlings, and the overflow of these into the tailings launder. The heads are washed off by jets of water; the middlings are spread in the usual way. The machine treats from 1 to $1\frac{1}{2}$ tons of ore per day.

There are in the laboratory, of course, the ordinary implements for panning and vanning to check the work done by jigging and slime washing, and to assist in amalgamating operations.

7. *Electro-Magnetic Separation.*—The magnetic separation of magnetite or of iron ore rendered magnetic by a preliminary roasting, is represented by a small Chase endless belt machine* placed near the tank [32]. This receives the waste water from a 6-inch

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* *Transactions American Institute of Mining Engineers,* xxi., 503.

Pelton water wheel which drives the concentrator. Many interesting data of magnetic separation are recorded in the journal of the laboratory. It may be incidentally remarked that a small Pelton wheel forms a most satisfactory motor for any apparatus that is to be driven independently in a laboratory having water under pressure at its disposal. Of course, a pressure regulator is necessary to equalize the uneven flow obtaining in a city main.

8. *Dry Concentration.*—There are no arrangements in the laboratory for dry concentration. To make tests that would be in any way satisfactory would require too much space.

9. *Distribution of Power and Water.*—The machinery of the laboratory is driven by a 15-horse power upright engine [24] having a common slide valve. Its cylinder is 9 inches in diameter; it has a 9-inch stroke, and is usually run at 200 revolutions per minute. The main shaft, $1\frac{3}{4}$ inches in diameter, is on the ground floor and runs the entire length of the milling room. Its position is approximately indicated by Nos. 1 and 3 in the plan (Fig. 1). It makes 240 revolutions per minute. Near the double ball-grinding mill [36.1] it is connected with the counter shaft of the same diameter placed near the ceiling. This also runs the entire length of the mill room along the center line of the Frue vanner. It makes 200 revolutions per minute. Thus the different machines are set in motion either from the main or the counter shaft, the choice depending upon the location and direction of the belts.

The large dynamo [25], an Eddy shunt-wound machine of 50 volts and 50 amperes, is driven at the rate of 2200 revolutions per minute. It has a separate driving shaft, $1\frac{3}{4}$ inches in diameter, making 550 revolutions per minute. The small dynamo [26], also an Eddy machine of 2 volts and 50 amperes, is connected with a counter shaft, and makes 1400 revolutions per minute. Electricity has so far been used in the laboratory only for the separation of ores and for the deposition of metals. For electric fusion a differently wound dynamo would have to be added, in order to secure the necessary amperage.

The water required in the laboratory is received from the city main, but is not conducted directly to the different machines, since there would be no regularity in the flow. It runs into the end compartment of the water tank [18], from the bottom of which a centrifrugal pump, 18 inches in diameter, delivers it into a 2-inch main pipe running along the upper platform, on which are placed the machines Nos. 13, 14, 18, etc. Two-inch tees supply the different machines from the top of the main. By the aid of separate pipes and 3-way cocks the overflow from the jigs can be pumped upon either the vanner or the round table, the overflow of the vanner upon the table, and the contents of the settlings tanks upon any of the washing machines or into the sewer.

10. *Auxiliary Apparatus.*—By referring to the plan (Fig. 1) and its legend, the different auxiliary apparatus used in ore-dressing and in metallurgical work can easily be seen. Prominent among these are, for instance, the steam drying-tables [19], on which the

products are dried so as to permit comparison of the weights of ore before and after treatment.

The plan does not show the thirty-odd large bins, 4 feet wide, 4 feet deep, and 4 feet high, for ores, fluxes, fuels, and intermediary products. They are accessible from the furnace room by two doors, and from the milling room by one door.

B.—Sampling and Assaying Apparatus.

Ore-sampling is generally done in the laboratory by hand. If it is desirable to do mechanical sampling, only intermittent machines—those which take the whole of a stream of ore at stated intervals—are allowable. The small-size machines of Bridgman and Constant do good work. Ores are crushed in the rock-breakers and rolls and pulverized in the Hendrie and Bolthoff sample grinder [5] or on bucking-plates [20]. Samples for analytical purposes are ground fine in four Morrel agate mortars [24.1]. The ores are all sampled by hand on the iron sampling floor [6] or on the sampling table [21]. Liquid pulp, fed upon or coming from washing machines, is passed through specially constructed automatic samplers (see *e. g.*, Fig. 2). Samples from alloys are taken by chipping, punching, sawing and boring [35]. In laboratory instruction too little stress is apt to be laid on the sampling of ores and metallurgical products. It is a most important and necessary part of the work, the whole of which is really invalidated if the sampling is inaccurate.

Assaying, in its broadest meaning, includes the quick quantitative determination of any element or compound met with in metallurgical work, embracing not only fire assays, but also what is known as analytical work on solids, liquids and gases. In the Institute metallurgical laboratory, assaying is restricted to fire work (except as regards the parting of doré silver buttons or chlorination assays). All analytical work is done in the chemical laboratories. The assay laboratory has two divisions: the assay room proper [37], and the balance room [44]. The assay room has eight pulp balances [39], weighing accurately to 1 milligram with a load of 60 grams, and six flux balances, accurate to 0.1 gram with a load of 600 grams. They are distributed among the students' desks [38], of which there are fifty. There are twelve crucible furnaces [41]; nine muffle furnaces [40], three of which have lately been erected in "the space to grow" [63]; and, lastly, an iron table [43] for hot crucibles, etc. Under the table is a shelf for crucible and scorifier molds, and beneath this are small bins for fuels. Along the side of the table are four posts, with anvils for breaking crucibles, hammering buttons, etc. The crucible furnaces are 27 inches high and 12 by 12 inches in the clear. They are inclosed in wrought-iron plates, and thus firmly held together. The top of each furnace is horizontal, and is covered by a fire-clay tile, around which is shrunk an iron band, with two hooks riveted to it. The cover is suspended from a wire cord passing over a pulley attached to the ceiling, a counter-weight being at the other end.

The muffle furnaces are of different kinds and sizes. Five are Judson coke furnaces, two with muffles, 4 by

7 inches, closed at one end, and three with muffles 8 by 16 inches, open at both ends; also, three coke furnaces, with sheet-iron housing and fire-brick lining, having muffles 7 by 12 inches, closed at one end; and, lastly, one two-muffle furnace for bituminous coal, with muffles 6 by 13 inches, open at both ends. Oil and gas furnaces are not used. The draft for all the furnaces is furnished by one main chimney [42], 2 by 3 feet, and about 80 feet high.

The balance room contains one analytical balance and nine button balances [45]. The principal aim has been to have the leading makers, such as Ainsworth, Becker, Oertling, Troemner, and others, represented. The balances are accurate to 0.01 milligram, with a maximum load of 0.5 gram.

C.—METALLURGICAL APPARATUS.

While the various operations of the concentration of ores and fuels can be carried on in a school or general experimental laboratory so as to give practical results, the case is likely to be somewhat altered when it comes to metallurgical processes. If we take, *e. g.*, a leading process, that of smelting in the blast-furnace, we cannot reduce the operations to a laboratory scale and obtain results which will serve as a guide for practical work. Nevertheless, smelting in the blast-furnace ought to be a part of the laboratory work, on account of its educational value. If a student receives for treatment a batch of ore, examines it mineralogically and chemically, makes the necessary analytical determinations of his fluxes and fuel, calculates his charge, smelts it and sums up his results by weighing, assaying, and analyzing the products, he learns more about smelting than any amount of lecturing or cursory visiting of works can ever teach him. Only by taking hold himself and carrying a process through to the end, can he learn how to think metallurgically, and thus become really qualified to listen intelligently to what is taught in the classroom.

There are, however, many metallurgical processes—such as roasting, amalgamating, leaching, electro-deposition and other operations—which can be performed in the laboratory on a small scale with trustworthy economic results. In fact, the engineer is guided, in the planning of amalgamating and leaching mills, by the results obtained in such laboratory experiments. This class of work should therefore have a prominent place in the laboratory. From what has been said, it will be evident that most operations relating to the metallurgy of iron and steel must be excluded. Attempts have been made to imitate large-scale iron and steel work in the laboratory. For instance, the Sheffield Technical School, in England, has a small open-hearth steel furnace; the Polytechnic School of Aix-la-Chapelle, Germany, has a small puddling furnace; but the writer, though not acquainted with the results obtained, is much inclined to doubt whether they will be found to justify the large outlay of time and labor involved. We must always keep in mind that it is not the province of an engineering school to perfect the student in any one branch of his profession, so much as to ground him in the fundamental principles upon which he is, later, to build for himself in detail.

In the laboratory of the Institute the processes chosen for instruction are those involved in the treatment of lead, copper, gold and silver ores, and the ores of some of the minor metals, although it should be added that crucible work and other small-scale heat treatment of iron and steel, especially with regard to their physical properties, are not excluded.

The furnace room [48] contains apparatus enough of various kinds to carry on all the necessary operations, so arranged as to occupy as little space as possible. This forces a crowding of the furnaces; but as the work can be so laid out that adjoining furnaces need not be used at the same time, less inconvenience results than might be at first supposed. The necessary draft is furnished by a stack [84] 2 by 3 feet, and about 80 feet high. A horizontal main flue, 3 by 3 feet, running along three sides of the room—sometimes near the ground, sometimes near the ceiling, according to the height of the furnaces—collects the gases. Each furnace, however, can be shut off from it by a damper in its branch flue. Too much stress can hardly be laid upon the necessity of securing a strong draft. The main and branch flues should be large, and the stack of ample section and sufficient height, so that it shall be possible to run each of the furnaces alone or any number or all of them together. With a well-fitting damper, it is an easy matter to cut off too much draft; if there is too little, the result is fatal.

1. *Roasting.*—For this purpose there are three reverberatory furnaces and one stall.

The large hand-reverberatory [56] covers 8 feet 2 inches by 5 feet 7 inches, and is 4 feet 8 inches high. Its hearth is 4 feet 2 inches long and 3 feet wide, and lies 9½ inches below the top of the fire-bridge, which is 9 inches wide. The height of the 9-inch side-wall is 11 inches to the spring of the arch, the height of the arch 5 inches. The furnace has one working door, 14 by 9 inches in size, and 2 feet 10 inches from the ground. The gases pass off through three openings, 9 by 9 inches, in the roof, into a branch flue running across the furnace and ending in the main flue. The fire-place, 2 feet 3 inches by 1 foot 9 inches, lies 16 inches below the top of the bridge, which is 8 inches below the roof. It has a door 12 by 9 inches in size, and 2 feet 6 inches from the ground. The furnace treats charges of about 250 pounds of pyritic ore.

The outside dimensions of the small hand-reverberatory [60] are: Length, 8 feet; width, 2 feet 8 inches; height, 5 feet. The hearth is 2 feet square and 6½ inches below the top of the bridge, which is 3 inches wide. The height of the 4½-inch side-wall is 8 inches to the spring of the arch, and that of the arch is 5½ inches. The working door is 9 by 6 inches, and 2 feet 10 inches from the floor; the flue running over the furnace is 5 inches square. The fireplace, 1 by 2 feet, is 10 inches below the top of the bridge, which is 7 inches below the roof; and its door, 9 by 6 inches, is 2 feet 6 inches above the floor. The furnace works small charges, of say, 25 pounds of pyritic ore.

The drawback of roasting in such small reverberatories is that the charge is liable to become too much cooled near the working door. If there had been more room, both roasting furnaces would have been constructed, like the reverberatory smelting furnace, with the working door at the end and the flue just above it, the air necessary for roasting being admitted through the hollow bridge. It might also be an improvement to have the hearth built in an iron pan, and so arranged as to permit its being removed, cleaned, and examined after an operation; although this is not so necessary in roasting as in smelting.

The third reverberatory roasting furnace, the Brückner cylinder [54 and Fig. 4], gives opportunity to study the behavior of an ore on a revolving hearth. The outside dimensions are: Length, 6 feet, and diameter 2 feet 8½ inches. The cylinder is of $\frac{3}{16}$-inch boiler-iron, and has a 2½-inch fire-brick lining. The throat is 12 inches, and the charging hole 8 inches in diameter. The cylinder, the axis of which is 3 feet 5 inches above the ground, revolves on two irom friction-rings (35 inches in diameter) which rest on four 12-inch carrying rollers. One of the carrying-roller shafts (2$\frac{7}{16}$ inches in diameter) is rotated by a worm gear (62 teeth of 1-inch pitch) at the rate of 20 revolutions per hour. The firebox is detached and rests on castor wheels. By removing the box backward or sidewise, the amount of air admitted can be increased. An additional improvement would be to make the throat of the firebox muffle-shaped, leaving that of the furnace circular. In order to have complete control over the flame, the grate (18 by 24 inches) is laid 20 inches below the bridge. The carbonic oxide gas generated is burned by warmed air entering the furnace just above the bridge, after having been forced through five flues in the side wall and roof of the firebox. The ash pit, 8 inches deep, is closed and connected with a blast pipe. This furnace treats charges of about 200 pounds.

The stall [57], which completes the roasting apparatus, is commonly used for treating coarse copper-bearing pyrites previous to smelting in the blast furnace. It is 3 feet 3 inches deep, 2 feet 3 inches wide and 3 feet 7 inches high to the spring of the arch. The arch is 6 inches high. The walls are 4 inches thick and well anchored. The oar is roasted on a temporary grate of wrought-iron bars. The front is bricked up half-way, the upper half being closed by an iron plate with peephole. The charge varies from 1500 to 2000 pounds, and a roast lasts from two to three days. The results in desulphurization are very similar to those in large stalls. The management of the stall affords a splendid lesson in the regulation of draft.

2. *Smelting.*—Smelting is carried on in the blast furnace, the reverberatory furnace and the crucible furnace.

The blast furnace [52 and Fig. 5] has had to undergo several changes before it reached the present satisfactory form. The first furnace, 18 by 15 inches at the tuyere level, was built of brick. It had one tuyere at the back, run with a "nose," the ore being charged towards the back and the fuel towards the front. It would last one day, or perhaps two days, and then had to be relined. The next furnace, 18 by 16 inches with three ordinary tuyeres, and charged in horizontal layers, burned out in less than a day. When provided, however, with one water-cooled tuyere at the back, projecting 8 inches, it was run successfully, and had to be relined only once a year. With this furnace ores were smelted for about six years, until, in 1884, the present one replaced it. This is a water-jacket furnace, resembling the circular copper smelter in common use to-day. The height of the furnace, 6 feet 6½ inches, is divided as follows: height of four hollow cast-iron columns, 17½ inches; thickness of annular collar, 1 inch; distance to tuyeres, 1 foot; diameter of tuyeres, 2 inches, and height to feed door, 3 feet 10 inches. The diameter at the bed plate is 1 foot 5 inches; at the tuyeres, 1 foot 6 inches; at the throat, 1 foot 11 inches. The furnace has a conical hood 2 feet 9 inches high and 25 and 11 inches in diameter, which ends in a vertical flue leading into the main flue. The feed door is 13 inches high, 14 and 9¾ inches wide. The water-jacket is of ⅜-inch boiler iron and has a 3-inch water space. The feed water is supplied from the city main through a ¾-inch pipe near the top, the overflow pipe being tapped into the upper flange. There are four tuyere holes, lined with solid bored blocks of bronze. The tuyere pipes are of wrought-iron steam pipe; the horizontal arm has at one end a conical turned bronze nozzle, at the other a T, the vertical leg of which is connected by a pipe with the tuyere bag, and the horizontal leg, reduced in diameter by a bushing, is closed with a cap having a glass-covered peep hole. The bustle pipe is 4 inches in diameter. The bottom of the furnace is closed by a wrought iron plate clamped to the collar of the four columns. The crucible is lined with brasque tamped in solid from above to the level of the tuyeres, and then cut out from below into the desired shape, the lining reaching up to the tuyeres.

In tapping the melted masses from the furnace different methods were tried before the present one was adopted. With an internal crucible and separate metal and slag taps the metal easily became cool; with an external crucible and continuous flow it cooled even more quickly. The present practice is to tap the melted masses into a small cast-iron overflow pot having the form of an inverted pyramid, 6 inches deep, 12½ inches square at the top and 2½ inches square at the bottom. This retains the metal, matte, and foul slag, and is removed after every tapping by means of iron hooks inserted through rings on either side. The clean slag overflows into an ordinary conical slag pot, 14 inches in diameter and 16½ inches deep. A detached carriage serves to take away the full pots and return the empty ones. A Devereux slag pot may in the future replace the arrangement now in use. The fumes from taphole and slag pot are drawn off by a hood connected with a small fan. The furnace has a daily smelting capacity of about 6 tons of charge, not counting the fuel. It is not run, however, for 24 hours at a time. The furnace, warmed during the preceding day and night, is usually blown in at 8 A. M. and blown down again about 4 P. M. This period is sufficient to give the student all the instruction that he can get from carrying on a smelting operation on such a small scale. Longer runs would mean greater physical exertion without corresponding benefit. When a run is completed, all the products are carefully separated, and, if necessary, the matte adhering to foul slag or metal is separated by an additional crucible fusion, and thus a complete account of stock is taken. With the present arrangements the loss of metal in flue dust has to be arrived at indirectly by difference. It is proposed, however, to save the flue dust, either by cooling or filtering or by wet condensation, and thus to obtain direct figures.

Three reverberatory smelting furnaces were once considered necessary to fill the wants of the laboratory for agglomerating lead and copper ores, smelting lead ores, cupelling base bullion, bringing forward matte and refining copper. Two furnaces are sufficient. The English cupelling furnace [59] serves for the last three operations; while the other two formerly carried on in a reverberator furnace (replaced to-day by the Brückner cylinder) will be taken up again when the copper refining furnace [55] has been rebuilt as a reverberatory furnace with movable hearth inclined from bridge to flue. The cupelling furnace is of the ordinary pattern. The test is 18 by 24 inches, and is wedged fast against the test ring; the fireplace, 18 by 24 inches, is run with the underwind; the grate is laid low, 20 inches below the top of the bridge, which is 9 inches wide and 15 inches below the roof. In order to burn the carbonic oxide gas formed, there is a special tuyere in the side of the furnace just above the level of the bridge. In addition to the tuyere at the back of the hearth, there is a second one in the roof connected with a U-shaped pipe passing through the flue. Hot blast comes into play when a quick raising of the temperature is desired. The different kinds of reverberatory work so far practiced in this furnace, such as liquating drosses on an iron plate, softening and cupelling base bullion on a hearth of limestone and clay, concentrating matte and refining copper on a hearth of a mixture of raw and burnt fire-clay or closely fitted refractory tiles have been so satisfactory that the idea of a fixed hearth for laboratory purposes has been entirely given up. In the furnace 150 pounds of base bullion, assaying about 150 ounces of silver per ton, are cupelled in 6 hours, or 200 pounds of black copper are brought through the different stages to tough pitch copper in 7 hours.

The plan [Fig. 1] shows a small cupelling furnace [61], which is used sometimes to refine impure silver from the English cupelling furnace in quantities larger than can be satisfactorily treated in one of the muffle furnaces. It has a small fireplace, 8 by 14 inches, and 15 inches deep, the flame rising from which strikes the fire-clay tile forming the roof, and is deflected so as to strike the silver (placed in an oval cupel-test, 8 by 14 inches, and 2 inches deep, filled with bone-ash).

Crucible work is of considerable importance in a metallurgical laboratory, as it is not only adapted for independant experiments, but serves to bring into suitable form the different mixed products obtained in the processes carried out on a larger scale in the laboratory. Small crucibles are commonly heated in the assay furnaces; for larger charges there are two pot furnaces [62, and Fig. 6], worked with under wind. They are fourteen inches square and 23 inches deep; the blast is introduced through the ash-pit door, and the ash-pit is 9 inches deep. A furnace holds conveniently a No. 35 graphite crucible.

3. *Distillation and Sublimation.*—Both these operations are of subordinate importance in laboratory work. Distillation of mercury is carried on in half-

pint and one-pint bulb-retorts, which are heated over four-tube Bunsen burners. The delivery pipe is cooled by suspending from it an iron trough filled with cotton waste, which is kept wet. Reduction of zinc oxide or sublimation of arsenic, realgar, and sulphur are rare operations, and no special apparatus is assigned for this purpose.

4. *Crystallization.*—The principal process coming under this head is the Pattinson process, for which a cast-iron kettle [58] is used, 21 inches in diameter and 14 inches deep, covered with a hood and heated by a fireplace 21 inches square. This kettle is rather small for the Pattinson process; it is the one in common use for deliverizing argentiferous lead by the Parkes process, and for melting and liquating, in general, readily fusible metals and alloys.

5. *Amalgamation.*—The process of amalgamation is especially well adapted for laboratory work, since small-scale experiments give results directly applicable to large-scale work. The different appliances for treating gold and silver ores in this way are therefore well-represented. There are a stamp-battery, a ball-mill, two revolving barrels and a number of pans of different sizes.

The stamp-battery, as a pulverizer, has already been described under the head of fine crushing. In using it for the amalgamation of gold ores, the arrangement and management of the copper plates (see Fig. 2) differ from those of large-scale work in having 9 small plates, 24 by 11 inches, and $\frac{1}{16}$ inch thick, laid crosswise over the apron table, one overlapping the other,* instead of a single large sheet of copper, and also in not having inside plates. By having several outside plates, and cleaning them up separately, it can be seen how the gold saved decreases with the distance from the mortar discharge, and the required length of plate can thus be tetermined. In order to prevent absorption of gold by the outside plate, it is coated with silver amalgam. On an inside plate this would be scoured off and gold would be absorbrd by the copper, thus violating the test; hence inside plates are not recommended.

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* Richards, *Transactions American Institute of Mining Engineers*, viii., 362; *Technology Quarterly*, iii., 45; Editorial, *Engineering and Mining Journal*, April 12, 1890, p. 418.

The ball-mill [36.1] is used for grinding and amalgamating small lots of gold ore and for cleaning up the battery residues. The plan shows a circular cast-iron [$\frac{3}{4}$-inch] plate, 22 inches in diameter, on either end of a horizontal shaft, 2 inches in diameter and 27 inches long, in the center of which is the driving pully, 20 inches in diameter. To each plate is bolted a flanged cylindrical box (7 inches deep, 17 inches in diameter and $1\frac{1}{2}$ inches thick), having a 4-inch charging hole opposite the shaft, to be closed by a wooden bung, and a $1\frac{1}{4}$-inch discharge opening, to be closed by a screw plug. From thirty to forty $1\frac{1}{2}$-inch steel balls do the grinding. The mill makes 48 revolutions per minute, and works two charges of 15 pounds of ore in about ten hours.

The revolving barrel [26.1] serves for amalgamating without grinding, as well as for leaching. Its general arrangement is similar to that of the ball-mill. To either end of the horizontal shaft, $1\frac{1}{2}$ inches in diameter and driven by a 20-inch pulley, is attached a wooden cylinder, 7 inches in diameter and 11 inches long, made of $\frac{7}{8}$-inch staves, which receives a 2-quart glass-stoppered fruit jar, made tight with a rubber washer and screw clamp. The jar is packed with felt into the wooden frame. The shaft makes from 20 to 25 revolutions per minute. Small lots of ore, of 1000 grams, more or less, are worked in about eight hours.

There are ten amalgamating pans [29 and 30, Figs. 7 and 8]. Three of these are accurate copies, in reduced size, of those used in practical work. They are 30, 18 and 12 inches in diameter, have sides 12, 8, and 6 inches deep, and discharge into a 30-inch settler, 12 inches deep, making 15 revolutions per minute. They treat charges of 250, 30 and 20 pounds, respectively, in from five to eight hours. The other seven pans [Fig. 8], especially constructed for laboratory experiments, are only 7 inches in diameter. Three of these are of copper; the others of iron. The pan has a solid central core and no dies; the muller and shoes are cast in one; the pulp is prevented from settling on the core and sides by adjustable scrapers. The muller can be raised or lowered on the driving shaft, which is driven from above and easily thrown in and out of gear. The pans are heated by Bunsen burners. The muller makes 90 revolutions per minute, and the pan works charges in three or more hours. The reason for choosing such small-sized pans is that in one day's work two students will finish without outside help a set of experiments. They start, for example, in the morning, four pans with the same ore, treat it in four different ways, and finish the cleaning up in the afternoon. A larger pan or a pan of a more complicated construction will not permit this. In cleaning up, a large-sized *Spitzlutte*, 3¾-inches in diameter and 13 inches high, with a ¾-inch water inlet-pipe is commonly used, as it does quick and effective work.

6. *Lixiviation.*—The leaching of ores and intermediary products can be done in the laboratory in stationary vats by percolation, or by mechanical stirring, or in revolving barrels. For leaching by percolation there are two forty-gallon vats (not shown in the plan, Fig 1), of wood lined with lead. These will be replaced with sheet-iron vats poured with melted roofing pitch. For leaching in stationary vats with mechanical stirring there are three sets of 8-gallon vessels [28 and Fig.9], of glazed earthenware, 12 inches in diameter and 14 inches deep. The wooden stirrers, with their iron driving shafts, make 75 revolutions per minute. For leaching in a revolving barrel the same apparatus is used as for amalgamation. Gold, silver, and copper ores are commonly, and zinc and nickel ores occasionally, treated by wet processes in the laboratory.

7. *Electro-Metallurgical Work.*—Electricity has so far been used only for the refining of silver- and gold-bearing copper. The large depositing table [27] holds the electrolytic baths. They are of wood pulp poured with melted roofing pitch, of glass, or of earthenware, as the case may be. No definite sizes have been, so far, adopted, but electrodes are usually made 7 by 10 inches. The current is furnished by the dynamos already referred to; thermo-piles and storage batteries are not in use.

D.—Conclusion.

It is somewhat difficut to estimate the cost of the laboratory apparatus, because one thing has been put in after another, and alterations have been frequently made. It could probably be duplicated for about $15,000. The annual cost of running the laboratory, excluding wages, fuel and power, is $1,200.

That it is conducted in connection with class room work, and not independently, need hardly be mentioned. With the school courses of the fourth year the students are thoroughly trained in the laboratory, their work there supplementing and illustrating the lectures. The last term is largely devoted to the working up of theses, which are always founded on laboratory experiment. While the student does not handle every apparatus, he sees most of them in operation. Every Saturday each student makes, before the assembled class, an oral report of his laboratory work during the past week, and its continuation for the coming one is discussed and laid out. The whole class thus gets the benefit of the work of each individual member. The time devoted to laboratory work is 325 hours, and to class room work, including preparation, during the same year, 225 hours. The most satisfactory arrangement would be to have during the entire year two days a week for laboratory work. One of these should be uninterrupted for making a complete experiment; the other might be divided into two half days.

Secretary's Note.—By consent of the Council, this paper has also been presented before the American Institute of Mining Engineers.

DISCUSSION.

THE PRESIDENT said that this suggested to him that there were two departments not sufficiently represented in this Society, mining engineering and electrical engineering. He believed that these two classes would profit by a better representation just as much as those which were already in. The papers which were read on Monday would apply as well to one as to another. He hoped that all present would use their influence to bring in their colleagues interested in other lines, as well as those in civil and mechanical engineering.

PROF. JOHN B. JOHNSON made an explanation of the presentation of a paper here that had been already read before another Society; it was by special request and consent that this was done. It was of equal interest to both, and for publication this Society could have the benefit of the cuts which have already been prepared.

A COURSE OF INSTRUCTION IN ENGINEERING MATERIALS.

BY J. B. JOHNSON.

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A thorough and systematic course of instruction in the strength of engineering materials, one-half of which should consist of laboratory work performed by the student himself, must now be regarded as absolutely essential to any fairly adequate college course in any line of engineering. No engineering design can be rationally planned and executed without this knowledge, and the only reason why this work has not always had due prominence given to it by the colleges is simply because the knowledge itself is only now coming to be so cöordinated and formulated as to be scientific and therefore teachable. The engineer's traditional "factor of safety" has been largely a factor of ignorance of the nature of his materials, and there has recently been, therefore, the greatest opportunity here for advancing the theory and practice of engineering. This opportunity has been embraced and the field occupied by hundreds of investigators, to the end that we are now in a position to teach to our students a great deal that is thoroughly scientific, which will very greatly lessen this "factor of ignorance" which engineers have so long been accustomed to employ.

In the opinion of the writer, an adequate course of instruction in this subject should now embrace the following:

(a). A review of the principles of mechanics.

(b). A study of testing machines and of methods of testing the strength of materials.

(c). A concise classification of the ordinary engineering materials and their methods of manufacture.

(d). Laboratory tests by the student of the strength and other qualities of the more common engineering materials.

Such a course should run for a year with three hours a week, one half of this time being given to lectures, (or recitations if a satisfactory text can be found), and the remainder to experimental work in the testing laboratory. While it is not essential that the course should closely follow any prescribed lines, the writer offers the following as a fair illustration of the quantity and quality of the work to be done.

(a) *A Review of the Principles of Mechanics.* The mechanics now·taught in technical colleges, as it relates to the strength of materials, applies only inside elastic limits and when friction is wholly neglected. This leads to sorry work when we come to apply the formulas to the strength of materials beyond the elastic limit and at rupture. Furthermore, there are several subjects not adequately treated in the text-books on mechanics.

Such matters as resilience, the relation of impact to static tests, the absorption of kinetic energy or *vis viva*, or of the quiescent energy or work of a testing machine on a specimen, within and beyond the elastic limits, the distribution of the absorbed energy through the mass of the specimen in various kinds of stress, and the resilience of the body when the distorting forces are removed; also the relation between

Young's and the valumetric modulus of elasticity, and between these and the shearing modulus, should receive additional treatment. By passing beyond the elastic limit we may explain the distribution of stress in cross-bending, and why the modulus of rupture here does not correspond with either the tension or the compression modulus. The distribution of the shearing stress in beams, and the rational design of wooden beams for shearing stress, should be taught.

By recognizing friction also, we are able to bring theory and fact into harmony in the matter of the crushing strength of brittle materials, and the relation this bears to the shearing strength, and the relation between crushing strength and the relative dimensions of the specimens. In these and in other ways, by reviewing the principles of mechanics as applied to the strength of materials, we can lay a theoretical foundation which will not have to be excused and abandoned at every turn on the ground of its being "theoretical" and hence not be expected to hold in actual practice.

This ground can be covered in about fifteen lectures.

(b) *Testing Machines and Methods of Testing.*—All the common types of testing machines used in America should be studied, first from diagrams or cuts supplemented by blackboard sketches, and then the students should be taken to the testing laboratory and the machines themselves examined and their operation explained. Before a student is asked to use any machine or instrument he should become familiar with its construction and with the principles on which it operates. Its limitations, defects, and weaknesses should be pointed out as well as its capacities. This study should extend to all the appliances used in connection with the machines, such as callipers, gauges, extensometers, autographic diagram apparatus, clutches, scales, moulds, gearing, pumps, etc.

The methods of operation of all these appliances could best be explained by actually using them before the class in the measuring and testing of a few specimens. If the school is not well supplied with testing machines and appliances, these may be studied from catalogues and drawings, and their operation explained as clearly as possible without the machines themselves. This will usually be necessary in the case of the Emery machines.* Not more than ten lectures are required for this part of the course.

(c) *Classification and Methods of Manufacture of Engineering Materials.*—This very large subject must be treated with great discretion in order to cover the ground in the time which can be given to it (say twenty-five lectures or recitations), and give the students that significant information which they most need to detect the difference between good and bad material, and to enable them to discriminate between them in the drawing of specifications. Little or no time should here be given to the history of these arts, but only the latest and most approved products and methods need be treated. While some attention should be given to such natural products as stone and timber, in order to develop the valuable characteristics of each for different purposes, the time should mostly be given to artificial or manufactured products, such as cement, brick, iron and steel, and the alloys.

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* A full description, with numerous detail drawings, of the Watertown Arsenal machine is to be found in the *Report of Chief of Ordnance, U. S. A.*, for 1883.

A brief but realistic description of the more common methods of manufacture of these products should be given, accompanied by drawings of factories and works, and this followed in each case with a discussion of the particular qualities the engineer desires the product to have, and the directions in which to look for failure. The success of this part of the course will depend on the success with which the instructor emphasizes the more important, and slights or overlooks entirely the more unimportant matters, so far as the use of these materials is concerned. With a knowledge of the good and bad qualities of those materials in mind, their cause, and the methods used by the engineer in detecting them, the instructor can so gauge his time, and so select the subject matter of his lectures, as to fairly cover this ground in the time here named, in a satisfactory manner. The time should mostly be given to iron and steel and cements. It would be helpful to imagine the student preparing himself to intelligently discharge the duties of an inspector of these materials, the instructor charging himself with the responsibility of fitting him for the task. (That the instructor is abundantly qualified to ably perform his part of the work goes without saying!)

(d). *Laboratory Tests of Materials.* An ideal arrangement would be to have the laboratory tests accompany, in time, the corresponding instruction on the qualities and methods of manufacture of each material in turn. This would require laboratory facilities sufficient to accomodate simultaneously the entire class on each kind of material. As this is an unreasonable demand, and is not likely to be met in any testing laboratory, it must be assumed that the lecture course has been entirely completed before the laboratory work begins. Then the class can be distributed among the entire laboratory outfit, and by rotation they will be able to use all of the appliances. The class should be divided into squads of three or four each, and all should work under competent direction. Their notes should be taken systematically in books provided especially for this work, and if these are made of double-ruled, or cross-section paper, it would be found very convenient for drawing sketches, for constructing strain diagrams and for column ruling. Each member of a squad should take all the notes of the work of his section, and these should be worked up independently for a check. If the use of the slide rule (preferably Thatcher's) has not been taught before in the course, it could well be brought in here, as it is really a necessary piece of apparatus in every testing laboratory. All tests should be fully worked up, and strain diagrams drawn whenever practicable. The modulus of elasticity of various materials should also be found, both in tension and in cross-bending, and the phenomena accompanying the passing of the elastic limit observed. The automatic strain diagram apparatus should be used some, if one is available, and also diagrams plotted from extensometer tests. It is not essential that all the squads of a class should perform exactly the same experiments, but all should do some work with all the machines and with all the standard materials.

It is always preferable, in the opinion of the writer, to have the specimens fully prepared outside the laboratory. The student can much better afford to pay for this work than to do it himself, unless the preparation can be made a part of his regular shopwork, which sometimes might be done. In general, the teacher should order the finished specimens and charge the cost to the members of the class the same as is done in a chemical laboratory. It may be wise to require for this purpose a deposit from each student before he enters upon his laboratory course. Cement briquettes are of course made by the students. It is thought this work should extend over a period of from fifty to sixty laboratory hours.

In the writer's opinion, the work should include tests on the following kinds of materials:

1. *Timber* in cross-breaking, crushing-endwise, crushing across-grain, shearing, and tension, together with determinations of the percentage of moisture. (Different squads might test different species.)

2. *Cast-Iron* in cross-breaking, tension (with extensometer) and crushing. The deflections should be observed in all cross-breaking tests of both wood and iron, and the strain diagrams drawn and the moduli of elasticity found. This modulus should also be computed in all cases of tension or compression tests when the extensometer is used.

3. *Wrought-Iron* in tension and cold-bending, both in plates and bars of various shapes, to develop effects of shape of specimen on the various results. Here

use both the automatic strain-diagram apparatus and also the extensometer. Have specimens prepared from widely different qualities of wrought iron, some from plates taken along the fibre and some across the fibre. The effects of punching and of other kinds of cold working can also be introduced if the class is large. The entire class will get the benefit of the work done by each squad, if an occasional "review hour" be given to this kind of comparison of notes. The students should, themselves, give to the whole class their results so far as they are different from the other.

4. *Structural Steel* in tension and cold bending, both in plates and bars, in specimens duplicating those of the wrought iron. These specimens should cover the entire range from very soft, or 55,000 lbs. steel, up to tool steel, with all the variations mentioned in the case of wrought-iron and perhaps others. The essentially fibrous nature of wrought-iron and the essentially crystalline nature of all grades of steel should be brought out by testing nicked and grooved specimens, both by bending and in tension, in order to forestall the common misconceptions in regard to the cold crystallization of iron and steel. Particular care should be given also to showing that in the soft and mild steels the true elastic limit coincides very closely indeed with the break-down point or what is commonly called the elastic limit (as indicated by the dropping of the beam) in commercial testing.

If specimens of soft steel be polished to a good mirror surface and then tested in tension or in cross-bending, and the test stopped at the right stage very beautiful effects can be produced, as indicated in the accompanying photographs. These are explained by the breaking-down of the material in diagonal planes, approximately at 45° with the direction of the principal stress, or on the planes of greatest shearing stress, and they will arouse great interest on the part of the students. The cost of the polished specimens is trifling.

If thought best, a variety of experiments may be planned to illustrate the truth of the ordinary formulas for the deflection of beams, by varying the supports and points of application of the loads, and the amounts of these, and measuring the deflections. The beam may also be made continuous over several supports, and loaded in any manner. If the beam be of a rectangular section, it can be turned both edgewise and flatwise, etc., etc., and so the truth of the formulas proven, so long as the elastic limit of the material is not exceeded. Small wooden beams are very suitable for this purpose, but the loads must not be left on any great length of time, for in the case of timber there is a time effect which the formulas do not provide for. All such experiments will be found to have great interest to students, and they can even design their own appliances for carrying them out.

Again, it will be said there is not time for this work in all engineering courses. I can only answer that we must then make the time. When four years is too short for what we think must be taught, then we must go to five years. I do not think this is necessery, however, as yet. We still waste a great deal of time in all our colleges, and we must learn to be more economical of that requisite to an engineer's education which we find we have the least of.

DISSCUSSION.

MR. WILLIAM KENT expressed surprise that Prof. Johnson should say that the breaking-down point and the elastic limit were the same, but felt inclined to believe him to be right. He wished Prof. Johnson would state what he meant by the breaking-down point.

PROF. JOHNSON replied that the elastic limit could be defined in two ways, both defining the same point, provided you are not "sticklers on second differentials." One definition was "the point beyond which the material takes a permanent set." The other was "the highest limit at which equal increments of stress produce equal increments of distortion." When material which had been rolled was subjected to pull for the first time after it had been rolled, it usually had a very little permanent set, even for small loads; therefore, before any material should properly be subjected to scientific work in the matter of elasticity, it should be put to a kind of proof stress. It should be loaded once, and the load removed before beginning an experiment. Then you would have brought it to what was called a "state of ease." The "breaking-down point" obtained in soft steel and some grades of soft iron, was the point at which the material began to flow. In other words, the strain or distortion increased under a constant, or even a diminishing load. Naturally, this did not occur before the elastic limit was passed. In what was generally called structural steel, which was really what the current discussion in the *Engineering News* was supposed to apply to, that had a decided breaking-down point. and he would regard the elastic limit and the breaking-down point as the point at which oblique superficial distortion lines began to appear. By matching the specimens it would be found that these markings would begin to appear when the breaking-down point was reached. The material broke down instantly. Those lines would be seen shooting across the specimen, gradually extending from one end of the specimen to the other, and it would be seen that the two terms were one and the same thing, practically. (The above remarks were accompanied by blackboard demonstrations by the speaker.)

Prof. John Galbraith desired to ask Prof. Johnson if he had made any experiments with ordiwrought iron, and if he had found in it any distinction between the elastic limit and the breaking-down point?

Prof. Johnson replied that he thought with some grades there might be some difference, but with the best grades of Swedish iron, or any iron that had decided breaking-down action, it would be found that the breaking-down point was not far away from the elastic limit.

In answer to another question he stated that people were not generally aware how cheaply machines could be obtained. A 20,000-pound Riehle testing machine cost him $225.00.

Prof. Mansfield Merriman said it seemed to him that a 150,000-pound Riehle testing machine was an unsuitable thing for a college laboratory. It was a commercial machine. There was not much to be learned from it, and he thought that the remarks about the laws of elasticity in Prof Johnson's paper were of more importance in the education of young men than work on the large machines.

Prof. Johnson replied that he did not at all believe in large machines in a college laboratory.

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N. C. State College

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